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Processing Chrome Tannery Effluent to Meet Best Available Treatment Standards

A. C. Lawrence Leather Co., Winchester, NH

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Processing Chrome Tannery Effluent to Meet Best Available Treatment Standards

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This report presents these data and describes the design and operation of the system. Possible applications of the same principles to other tannery wastewaters are also suggested.

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PROCESSING CHROME TANNERY EFFLUENT TO MEET BEST AVAILABLE TREATMENT STANDARDS

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory-Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

The A. C. Lawrence Co. has demonstrated a highly efficient wastewater treatment system at their chrome tannery in Winchester, N. H. The system uses flow equalization, primary treatment by chemical addition and air floation, and secondary treatment in an oxidation ditch. Removal of both carbonaceous and nitrogenous materials was accomplished. This study will be of great interest to the entire leather tanning industry. The Food and Wood Products Branch, IERL-Ci, may be contacted for further information on the subject.

David G. Stephan
Director
Industrial Environmental Research Laboratory
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ABSTRACT

To satisfy stream discharge requirements at its Winchester, N. H., chrome tan shearling tannery, the A. C. Lawrence Leather Co., Inc. selected primary and secondary systems that are unique as applied to tannery effluent treatment in the United States. Primary clarification is accomplished by means of coagulation and flotation, using electrolytic as well as mechanical micro-bubble generation. The secondary biological section is a so-called CARROUSEL,™ a technical modification of the Passveer oxidation ditch. During the 12-month study, complete analytical data representing winter as well as summer operating conditions were acquired along with operating cost data.

This report presents these data and describes the design and operation of the system. Possible applications of the same principles to other tannery wastewaters are also suggested.

This report was submitted in fulfillment of Grant No. S 804504 by the A. C. Lawrence Leather Co., Inc., under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period September 15, 1976 through March 31, 1978 , and work was completed as of March 1, 1978.

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CONVERSION TABLE

Multiply (English Units)	by	To Obtain Metric Units
English Unit	Conversion	Metric Unit
British Thermal Unit	0.252	kilogram-calories
British Thermal Unit/pound	0.555	kilogram calories/kilogram
cubic foot/minute	0.028	cubic meter/minute
cubic foot/second	1.7	cubic meter/minute
cubic foot	0.028	cubic meter
cubic foot	28.32	liters
cubic inch	16.39	cubic centimeters
degree Fahrenheit	0.555(°F-32)*	degree Centigrade
foot	0.3048	meter
gallon	3.785	liters
gallon/minute	0.0631	liter/second
horsepower	0.7457	kilowatt
inch	2.54	centimeters
pound	0.454	kilogram
million gallons/day	3,785	cubic meters/day
pound/square inch (gauge)	(0.06805 psig+1)*	atmospheres (absolute)
square foot	0.0929	square meter
square inch	6.452	square centimeters
tons (short)	0.907	metric tons (1000 Kilogram)
yard	0.9144	meter

*Actual conversion, not a multiplier

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The project is also indebted to Mr. Francis E. Stone, Plant Manager at Winchester, who maintained a keen interest and directed prompt attention to necessary maintenance details thus providing continuity of operation.

It is also appropriate to acknowledge the direction and assistance of Mr. Jack L. Witherow and Mr. Donald F. Anderson of the U.S.E.P.A. whose capable guidance was essential to this project.

SECTION 1

INTRODUCTION

Tanneries are generally pollution-intensive industrial complexes generating large volumes of high-concentration wastewaters. These wastes have historically been discharged into rivers and waterways with little if any purification. This report presents construction and operating data, including analytical results, for a system designed to eliminate most of the objectionable components of a tannery effluent formerly discharged directly into a small river.

Tanneries are not all alike. The basic design of procedures for hide preparation, tanning, and finishing vary rather widely according to the types of raw hides employed and the characteristics desired in the finished leather product. Accordingly, the U.S. Environmental Protection Agency (EPA) has classified the various segments of the industry into the following seven categories:

1. Cattlehide - pulp hair - chrome tan
2. Cattlehide - save hair - chrome tan
3. Cattlehide - non chrome tan
4. Thru-the blue
5. Retan only
6. No beamhouse tannery
7. Shearlings

The tannery investigated here is a shearling tannery, which tans and finishes sheep pelts with the wool intact. These skins, except for the alterations of character and appearance needed to accomplish permanent preservation and enhance aesthetic qualities, are essentially the same entity removed from the parent animal. The pelts are received at the Winchester tannery either green salted or dry salted in railroad cars or auto trucks from large-scale meat producing points in the Midwest, Far West, or Atlantic seaboard. The pelts contain large amounts of animal grease and interfibrillary, water-soluble, proteinaceous compounds in the form of glycomucins and the like, as well as large quantities of lanolin, wool grease, and soil attached to or entrapped in the wool. These components are removed early in the processing procedure during washing operations, which coax the grease and lanolin into dispersal through the use of strong detergents and emulsifiers.

The basic difference between a shearling tannery and a conventional cattlehide tannery is that the former requires no dehairing steps. This process, known as beamhouse operations, involves the use of chemical agents such as lime and sodium sulfide to produce either cattle hair suitable for resale or denatured (pulped) hair, most of which enters the waste stream in the form of fine particles. Section 2 describes the shearling process, and Section 9 presents designs for complete cattlehide processing systems.

The wastewater treatment system selected for the Winchester tannery was chosen from a number of options. The electrochemical primary system, sometimes called LectroClear, was favored for several reasons:

1. The presence of large quantities spent fatliquor solutions and emulsified lanolin, wool grease, and animal fat all well dispersed, dictated a clarification system that would involve flotation rather than gravity separation.
2. Laboratory-scale demonstrations clearly indicated that the floated skimmings would have a much higher solids content (perhaps on the order of 10X) than a gravity system could deliver. Sludge storage, handling, and dewatering would thus be expedited.
3. The continued flotation effect provided by the electrodes in the flotation basin seemed to maximize primary clarification.
4. The electrolytic generation of chlorine coincident with the other products of electrolysis appeared to have the beneficial side effect of providing some disinfection.
5. At the time of selection, ammonia reduction was thought to be occurring within the LectroClear system. This effect was a possible plus, but it was later found to be untrue.

The secondary system was likewise selected from a number of possible choices. The carrousel concept, which is a technical modification of the Passveer oxidation ditch, was brought to our attention by EPA and leather industry representatives who visited Holland in 1974. They reported rather enthusiastically the simplicity of design, low cost, minimum land requirement, adaptability to northern winter climate operation, ease of control of dissolved oxygen, and low operating cost. In addition, the most important, this system was claimed to have the capability of both nitrifying and denitrifying. Because all of these factors seemed to indicate superiority over other known systems, consultant help was secured, and the decision made to install a carrousel unit.

The choice of a sludge dewatering device was affected by the fact that the land area of the tannery property was limited, and solid waste from the treatment plant thus had to be deposited at the regional solid waste management facility. Samples were submitted. The material was accepted with the stipulation that the dry solids content would consistently have to reach 35% to 40% (and preferably 40%). Only one device, a filter press, could reliably be expected to provide this performance.

The choices made in assembling this treatment plant have proved to be wise. Consistently high-degree removals of pollutants have been achieved, in most cases well in excess of discharge permit requirements.

SECTION 2

WET PROCESS DESCRIPTION

Shearling processing is a complex procedure using a much greater water-to-hide ratio than most tanneries. Because the wool is retained and it is desirable to keep the wool fibers attached to the pelts free from interweaving and tangling, the practice of swimming the skins in chemical solutions has been adopted. Other categories of tanning operations limit the chemical floats to the smallest possible amounts. The liquor-to-skin ratio, by weight, for each fill and drain is on the order of 2.5 to 1. With side leather, the ratio is apt to be 1 to 1, and in some individual instances, it may be as little as 0.25 to 1. The Winchester tannery uses approximately 90 gal of water per pelt (7,500 gal per 1,000 lb of green salted weight as received), or on a weight basis, a ratio of 60 to 1. This seems very high, but is necessitated primarily by the extremely soiled condition of the pelts as received.

The tannery processes some 3,000 skins per day and discharges just under 300,000 gal of wastewater per day.

The process used at Winchester has evolved over many years of trial and error and has gradually been optimized by experience. There is no close-knit shearling trade group in the U.S. exchanging ideas for mutual benefit, nor is there any standard procedure for converting raw pelts into finished products. Many tannages are used in this tannery, ranging from glutaraldehyde to modified mineral and vegetable tannages, depending on the end use and characteristics desired in the finished shearling. The shearling process consists of soaking and washing, pickling, tanning, retanning, dyeing, and fatliquoring, drying, and dry finishing. This section describes the wet processing steps, or those contributing to liquid waste volumes.

SOAKING AND WASHING

Chemicals used in the soaking and washing process are soda ash, detergents (biodegradable), and bactericide. Skins are immersed in water in batches of about 100 in a horizontal, semicylindrical wooden tub, on which a paddle wheel is mounted. The above chemicals are added, and the paddle wheel is rotated to provide a swirling action that enhances liquid contact with both the skin and the wool. A number of fills and draws are executed during the wash and rinse cycles. This is a overnight operation.

PICKLING

Chemicals used in the pickling process include sodium chloride and sulfuric acid. Skins are immersed again in paddle vats and gently agitated, this time in 5% salt brine containing sulfuric acid sufficient to adjust and maintain the pH to about 1.8. This operation is also an overnight one. Equiblibrium at the pH specified is achieved.

TANNING

Chemicals used in the tanning process are sodium chloride, basic chromium sulfate, and sodium formate.

Skins are again immersed and gently agitated in paddle vats to which the chromium tanning solution has been added. This requires a 2-day exposure. In some cases, depending on the product desired, the chromium solutions are retained and reused. In others, certain dyes are added that prevent reuse.

RETANNING, DYEING, AND FATLIQUORING

Chemicals used in this process are sodium chloride, basic chromium sulfate, sodium formate, emulsified animal, vegetable, fish, and mineral oils, and various dyestuffs. Similar equipment to that described in the foregoing steps is employed. The only significant difference in the dyeing and fatliquoring sequence is that much higher temperatures can be tolerated by the now chrome-tanned skins, and such elevations can be used to advantage in the exhaustion of the dye baths and fixation of the dyestuffs. The time periods required are relatively short - on the order of 2 to 3 hr.

All of the above operations are carried on at the ground-floor level of the tannery, and the liquid contents of the paddle vats discharge by gravity to in-floor drains and sewers. This means that it is possible for a number of vats to be discharging dissimilar solutions to the wastewater collection system at the same time. Generally the soak waters are the first to be sewered in the workday, beginning at about 3 a.m. and lasting until 3 p.m. The pickle liquors are dropped from about 11 p.m. to 11 a.m. The tan liquors from 7 a.m. to 2 p.m., and the color-fatliquor solutions from 7 a.m. to 3 p.m. The equalizing tank at the front end of the wastewater treatment works blends dissimilar solutions and absorbs surges in hydraulic flows.

The blended waste stream is thus a complex mixture of organic and inorganic chemicals, mineral and vegetable tanning materials, animal, mineral, and vegetable oils, both raw and solubilized, and a spectrum of dyes. It is a murky brew at best, sometimes red, sometimes blue, usually dirty gray, but always a challenge to any sanitary engineer. A typical analysis of a composite sample from the equalizing holding tank is as follows:

TABLE 1. TYPICAL WINCHESTER TANNERY EFFLUENT ANALYSIS

Parameter	mg/l
Suspended solids	1,150
BOD_5	812
NH_4-N	32
TKN	75
FOG	450
Cr	99

Though this analysis may not appear to represent contamination loads encountered at chrome side tanneries, it is not as different as one might expect (See Section 9).

SECTION 3

TREATMENT PLANT COMPONENTS

Treatment plant components are described briefly as follows. Schematic views of the primary and secondary treatment systems, the constant head box, the primary clarifier, and the carrousel are presented as Figures 1, 4, 9, and 11.

PRIMARY CLARIFICATION SECTION

Screen House

The screen house contains a screen pit with a horizontal cylindrical rotating monel screen. The screen measures 3 ft. diameter by 5 ft. long and has 5/32 in. perforations on 1/2 in. centers. It is equipped with link chain mounted bar rakes that continuously remove accumulated coarse suspended solids.

Manufacturer: Exeter Machine Co., Inc.
Lomura, Wisconsin

Raw Wastewater Pumps - 3

These are submerged pumps located in a sump adjacent to and having a water level the same as the screen pit referred to above. These pumps elevate the wastewater to the equalizing tank as required, and are actuated by float switches in the collection sump.

Manufacturer: Flyte Corp.
Model No. - 6 - CP - 3126
Capacity - 600 gpm. Mhp - 9.4

Holding and Equalizing Tank

See Figure 2.

This is used to accumulate wastewater during working hours, absorb flow surges, and serve as a supply tank to allow constant flow through the treatment system.

Construction: Concrete, circular.
Size - 40 ft. diam. x 18 ft. deep
Capacity - 170,000 gals.

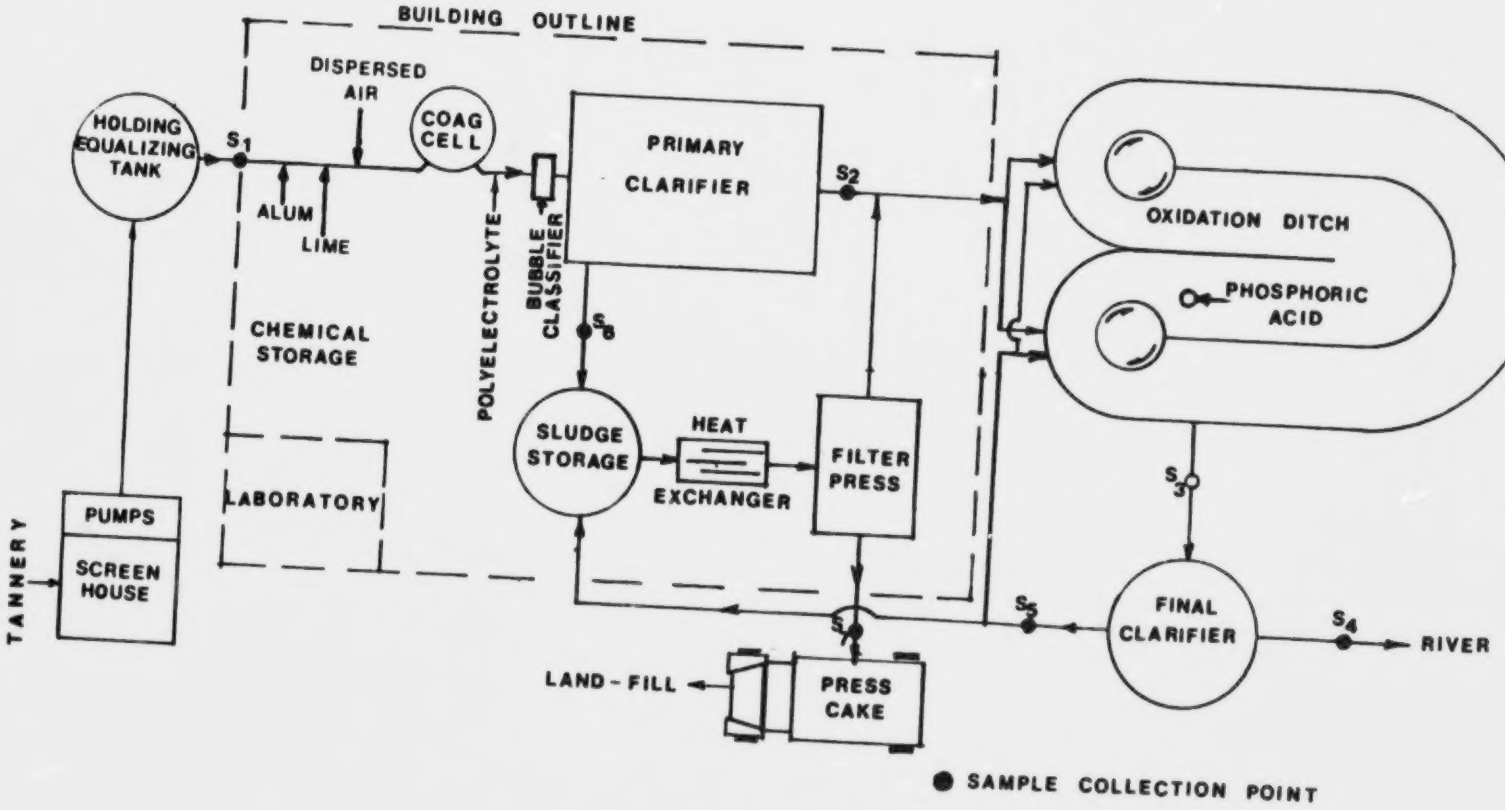


Figure 1. Schematic diagram of Winchester treatment plant.

Supply Pumps - 2

These are submerged pumps located near the bottom of the holding tank. They are activated by float switches mounted near the bottom of the tank. They elevate the wastewater to the constant-flow head box - see next item.

Manufacturer - Same as raw wastewater pumps above.
Model and Capacity - Same as raw wastewater pumps above.

Constant-Flow Head Box

See Figures 3 and 4.

This consists of a fiberglass vessel, cylindrical, open top, which has an adjustable side weir with which to regulate the depth of water within it. It has two bottom connections, one to supply - pumps located directly below in the holding tank, the other to the treatment plant. It is located within the holding tank, near the top, attached to the perimeter. Wastewater is pumped upward into the head box in an amount greater than can be absorbed by gravity flow through the system. The excess overflows the adjustable weir and cascades back into the holding tank, creating turbulence beneficial to solids suspension and hydraulic mixing. The constant head provides a constant rate of flow to and through the system until the water level in the holding tank is reduced to the point that the level sensing switch shuts the primary system down.

Diameter (ft) - - - 4
Depth (ft) - - - 6.75
Volume (ft^3) - - - 84
Design flow (gpm) - - 400
Design flow (gpm/ft^2)- 63.5
Design flow (gpm/ft^3)- 9.5

Dosing Pump - Alum

This is a small centrifugal pump used to meter in alum solution (45% wt. solids) from a fiberglass storage tank holding a 24 hr. supply.

Manufacturer -Liquiflo Equipment Co.
Series 34 3gpm 1/2 in. 316SS.
Motor - G.E. 0.75 hp DC
Variable speed 1725 rpm max.

Dosing Pump - Lime

This is an air actuated diaphragm pump used to add lime slurry (10% solids) to the wastewater stream from a continuously agitated storage tank holding a 24 hour supply.

Manufacturer - Dorr Oliver Corp.
Diaphragm slurry pump
Model ODS 1½ in. - Comp. Air 45 psi.

Figure 2. Holding and Equalizing Tank

Figure 3. Constant Head Box

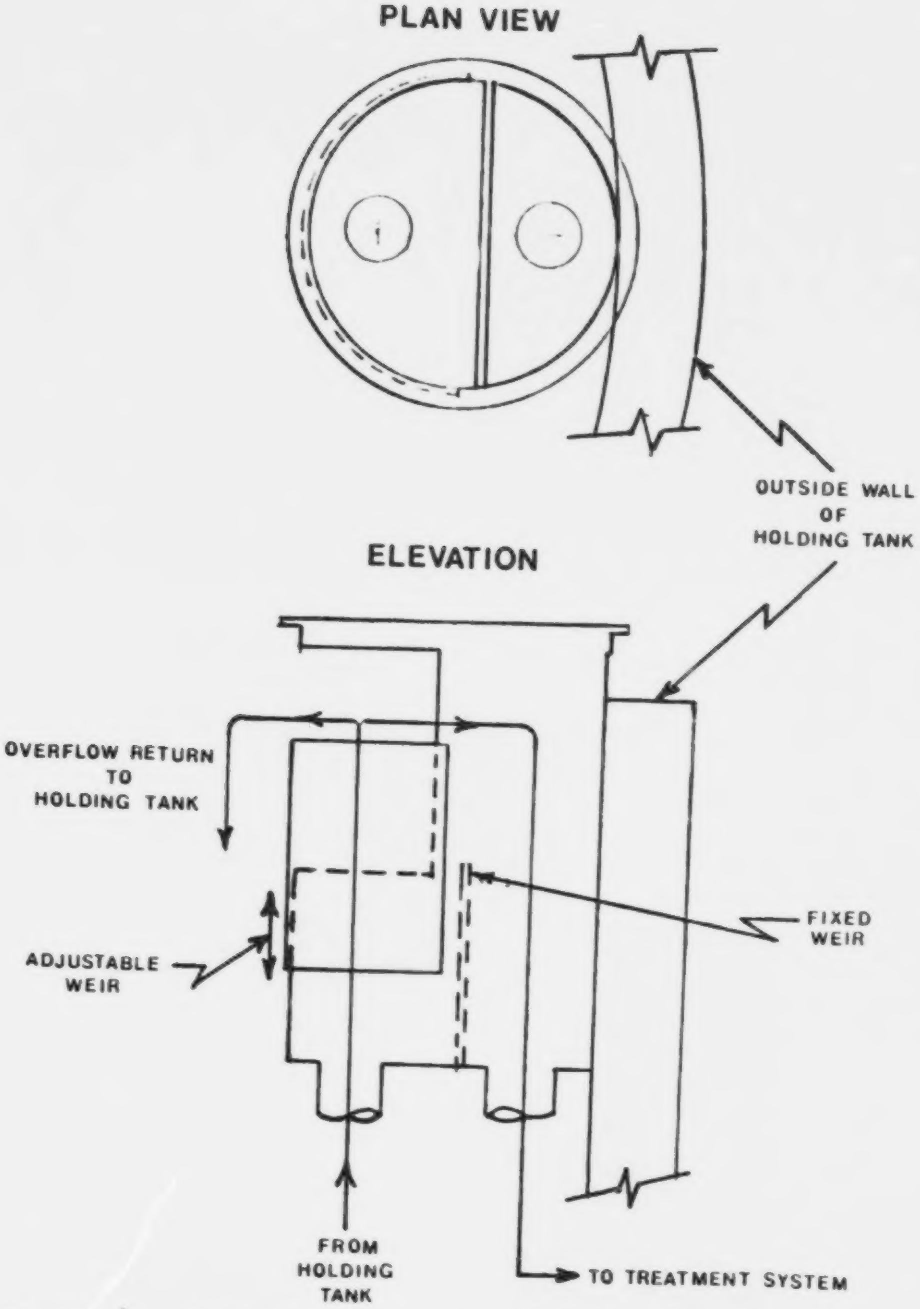


Figure 4. Schematic diagram of Constant Head Box.

Dispersed Air Generator

See Figure 5.

This is an in-line mixer used to provide high frequency agitation for dispersing compressed air introduced to it into fine microbubbles for floc flotation.

Manufacturer - Greey Mixers, Ltd.
Toronto, Canada
Model No. - 4-LBC-200 Lightning
Impeller - 5 in. diam. 316 SS.
Motor - 2 HP 1150 rpm.

Coagulation Cell

See Figure 6

This is a sheet iron vessel consisting of a cylindrical top section and a rectangular bottom section. It allows intimate contact to develop between microbubbles and minute solids in suspension. The wastewater flow enters the chambers tangentially at the lower level and leaves tangentially at the upper level, thus providing a vortex action. Effective residence time ±2 minutes.

Manufacturer: Local sheet metal fabricator
Plans furnished by Swift Environmental Systems, Oak Brook, Illinois
Diameter top section (ft) - - - - - - - - 7.6
Depth top section (ft) - - - - - - - - 2.5
Length bottom section (ft) - - - - - - - - 7.6
Width bottom section (ft) - - - - - - - - 7.6
Depth bottom section (ft) - - - - - - - - 1.8

Dosing Pump - Polyelectrolyte

This is a small centrifugal pump used to continuously add polyelectrolyte solution in small quantity to the waste stream from a stock tank holding 24 hr. supply.

Manufacturer - Liquidflo Equipment Co.
Series 36 5 gpm 3/4 in 316 SS
Motor: G.E. 0.75 HP D.C.
Variable speed 1725 rpm max.

Bubble Classifier

See Figure 7

This is a rectangular open top steel tank located in the line of flow between the coagulation cell and the LectroClear basin. The wastewater leaving the coagulation cell contains some bubbles which are too large to be effective in floc flotation and cause agitation and disruption of the sludge

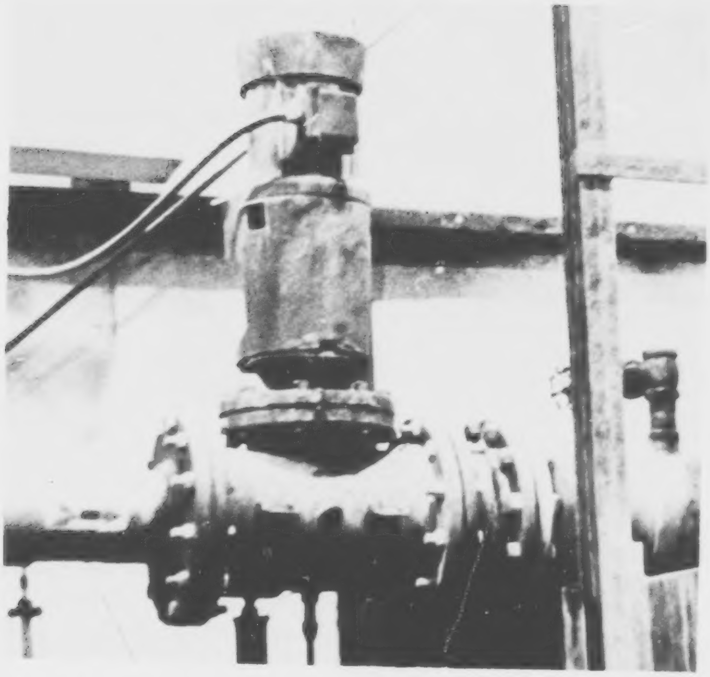


Figure 5. Dispersed Air Generator

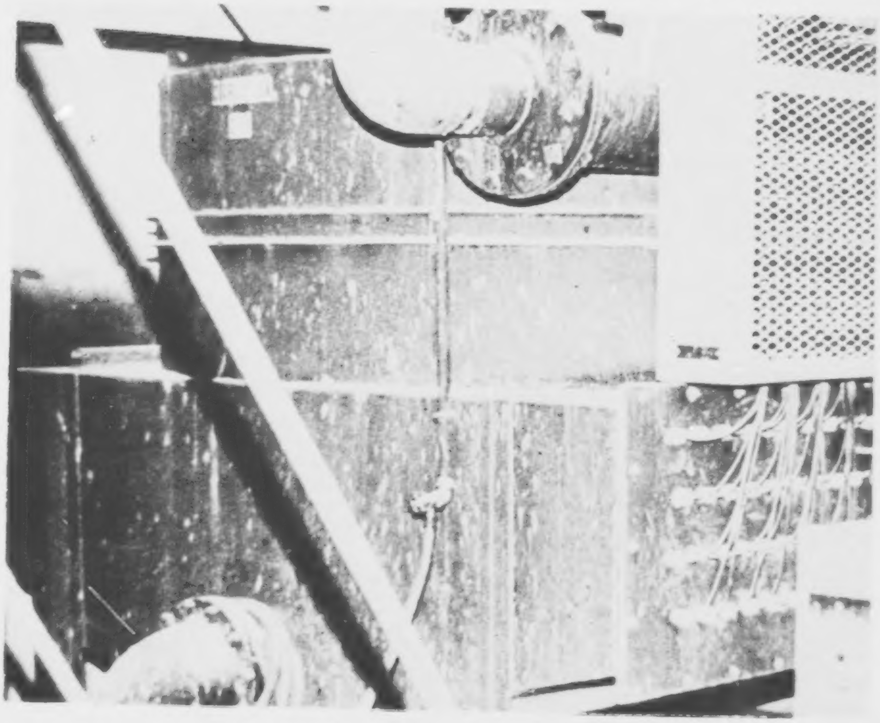


Figure 6. Coagulation Cell

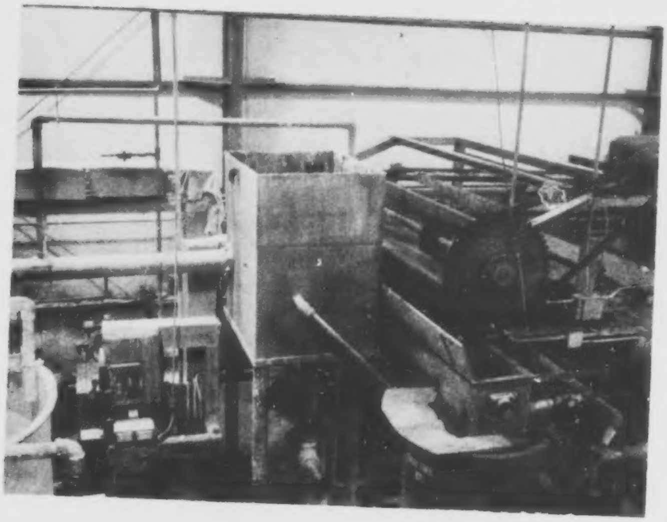


Figure 7. Bubble Classifier

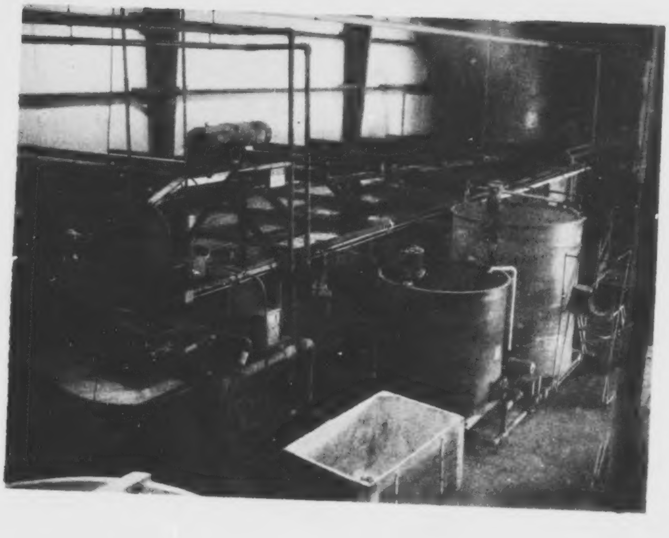


Figure 8. LectroClear Flotation Basin

blanket at the surface of the primary clarifier. This vessel allows oversize bubbles to escape to the atmosphere prior to entering the primary clarifier.

Manufacturer - Local sheet metal fabricator

Length (ft)	4
Width (ft)	3
Depth (ft)	4.5

LectroClear Clarifier [1,2,3,4,5,6]

See Figures 8 and 9.

This is a large rectangular steel tank in which coagulated suspended solids rise to the surface, and are continuously skimmed off. Skimmer flights are mounted on the top of the tank structure, 10' apart, traveling at 2.5' per min. Travel is continuous while the system is operating. Floating solids are pushed forward and up a beach into a continuously rotating screw conveyor. The conveyor discharges the skimmed material into a receiving tank from which it is intermittently transferred to storage tanks to await compaction. In order to avoid flow channelling in the basin, 4 baffles, equally spaced, with 67% free space consisting of 3 in. holes on 4 in. centers, are equally spaced about 7 ft. apart in the clarifier. These are made of marine plywood. The clarifier contains 78, 2 3/16 in. diam. Duriron electrodes, Type TA-2. They are operated in pairs with a surface to surface spacing of half an inch. They are mounted in polypropylene cradles 10 in. above the basin bottom. One half of the electrodes are concentrated in the front quartile of the clarifier.

Manufacturer - Local sheet metal fabricator

Length (ft)	35
Width (ft)	12
Depth (ft)	5.5
Operating depth (ft)	5
Current requirement - amperes	1400 to 1700
Current requirement - volts	6 to 7 DC

Current Rectifier

This unit is used to furnish direct current to the electrodes in the LectroClear clarifier for generation of electrolytic microbubbles to assist in floc flotation.

Manufacturer - Oxymetal Industrial Corp., Warren, Michigan
Model - Udalite No. 4 MDV - 5000
Type - SASS C 460V
Water cooled.

Skimmings Pump

See Figure 9.

This is an open impeller centrifugal trash pump used to move skimmings from the receiving tank at the LectroClear clarifier to the skimmings storage

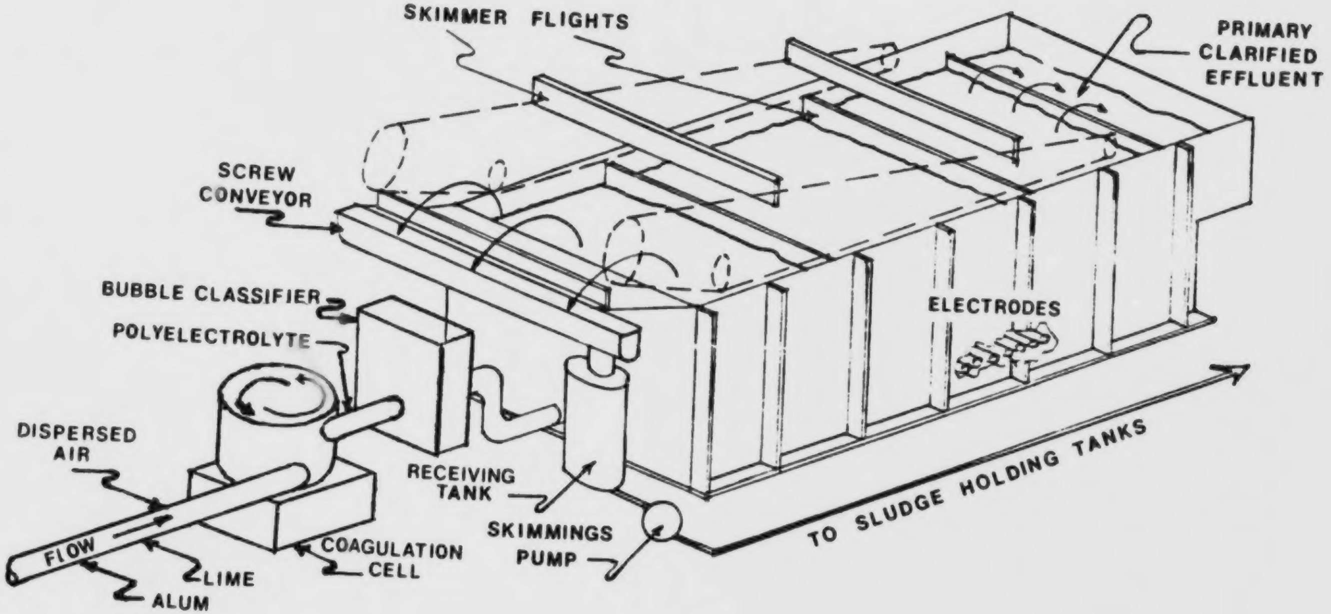


Figure 9. Schematic diagram of LectroClear system

tank. It is actuated by a float switch in the receiving tank.

Manufacturer - Gorman Rupp Co.
Capacity (gpm) - - - - - - - - - - - - - - 100
Model - 3 in Centrifugal
Motor - 3 HP 1750 rpm

Sludge Storage Tanks

These are large cylindrical steel tanks used to store and accumulate primary clarifier sludge and return sludge from the secondary final clarifier to allow compaction to be carried out at a convenient time.

Manufacturer - Local sheet metal fabricator
Height (ft) - - - - - - - - - - - - - - - - - - 15
Diameter (ft) - - -- - - - - - - - - - - - - 12
Volume (gal) - - - - - - - - - - - - - - - - - 12000
Steel thickness (in) - - - - - - - - - - - - 3/8
Number - 2

SLUDGE COMPACTION SECTION

Sludge Compaction Pump

This is an air actuated diaphragm pump which forces sludge from the sludge storage tanks through steam heated tubular heat exchangers and through the filter press.

Manufacturer - Warren Rupp Pump Co. Mansfield, Ohio
Model No. - SA3A Sand Piper
Air Actuation (psi) - - - - - - - - - - - 75

Heat Exchangers

These are used to elevate the temperature of the stored primary and secondary sludge to 175 F to aid in filter press compaction. Operated in parallel.

Manufacturer - Eimco, Inc.
Length (ft) - - - - - - - - - - - - - - - - 14
Shell diameter (in) - - - - - - - - - - - - 8
Design - Two pass
    Tube diameter (in) - - - - - - - - 0.5
    Number of tubes each pass - - - 12
    Stainless steel 316
Number - 2

Air Compressor

This unit is used to supply compressed air to the sludge compaction diaphragm pump and to the dispersed air generator.

Manufacturer - Kellog American
Model No. B-462
Motor HP - - - - - - - - - - - - - - - - - 25
Pressure (psi) - - - - - - - - - - - - - - 100 to 125

Filter Press

See Figure 10.

This unit dewaters and compacts sludges produced in the primary and secondary sections to the degree required by state regulations for land-fill material.

Manufacturer - Sperry Equipment Co.
East Aurora, Illinois
Model No. 48EHCL
Number of plates - - - - - - - - - - - - - - - - 75
Plate design
    Width (in) - - - - - - - - - - - - - - - - - 48
    Height (in) - - - - - - - - - - - - - - - - 48
    Feed port - - - - - - - - - - - - - - - - - Center
    Feed vent - - - - - - - - - - - - - - - - - Corner
    Face pattern - - - - - - - - - - - - - - - - Pyramid
Filter cloth fabric - - - - - - - - - - - - - - Polyester
nonwoven

BIOLOGICAL REDUCTION SECTION

Carrousel Oxidation Ditch [7,8,9,10,11,12 13]

See Figures 11, 12, 13,

This is one of the major components of the entire treatment system. It is a closed loop raceway of patented design constructed of concrete, mostly below grade. Two aerators, mounted at specific locations, provide dissolved oxygen by aeration and hydraulic force for continuous circulation of contents through the channels.

Manufacturer - Local construction contractor
Design and specifications - Envirobic Systems, Inc., New York, N. Y.
Design F/M ratio -(BOD/MLSS) - - - - - - - - - - - - - - -
Design MLSS (mg/l) - - - - - - - - - - - - - - - - - - 0.06
Length over-all (ft) - - - - - - - - - - - - - - - - - -5500
Width over-all (ft) - - - - - - - - - - - - - - - - - - 123
Operating depth under aerators (in) - - - - - - - - - - - 66
Operating depth in channels (in) - - - - - - - - - - - - 98
Operating volume (gal) - - - - - - - - - - - - - - - - - 79
Channel length - total (ft) - - - - - - - - - - - - - - 380,000
610

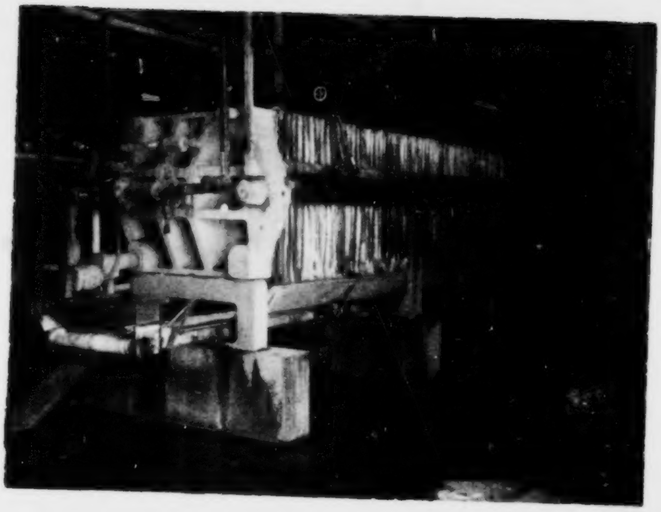


Figure 10. Filter Press

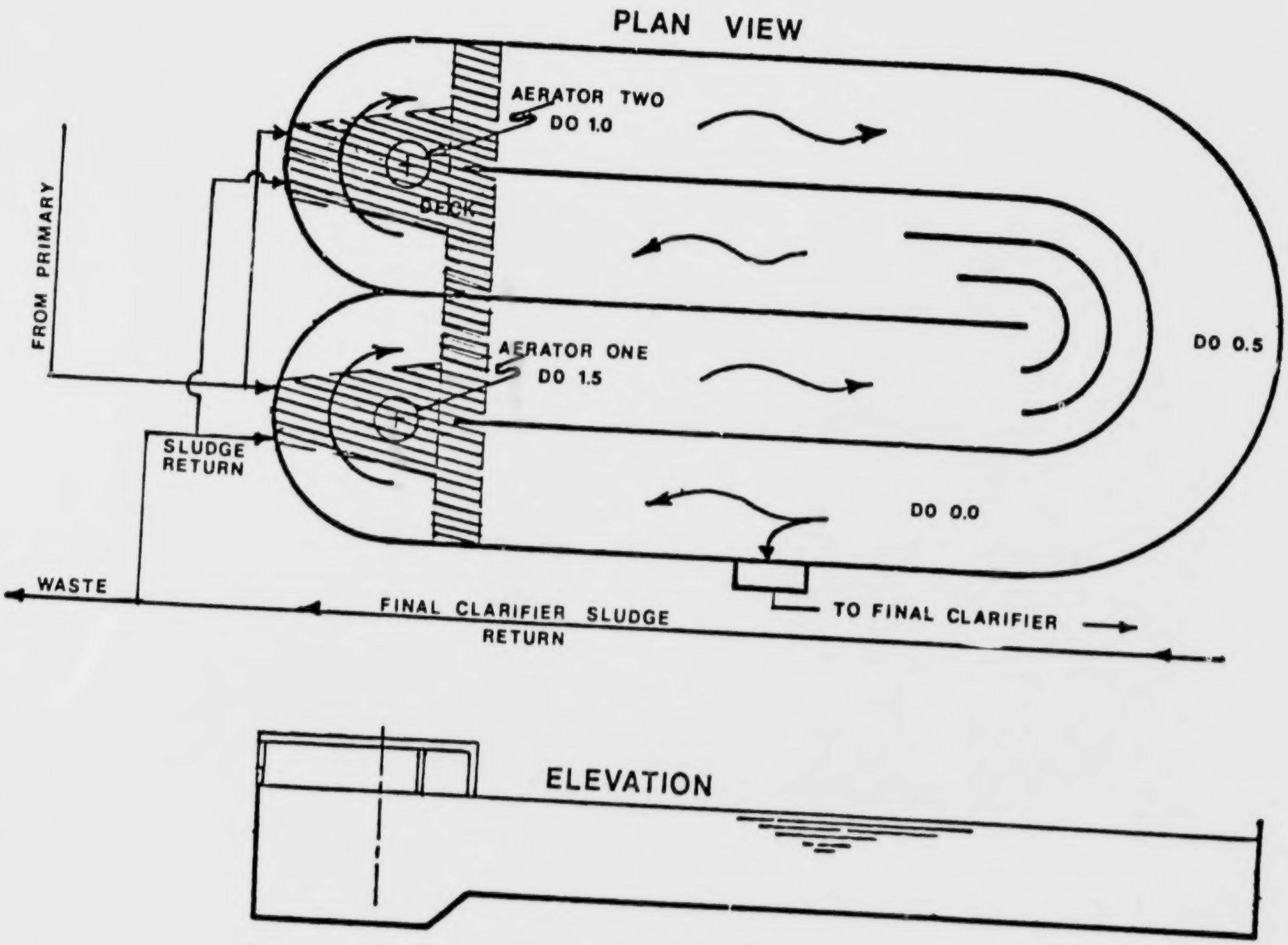
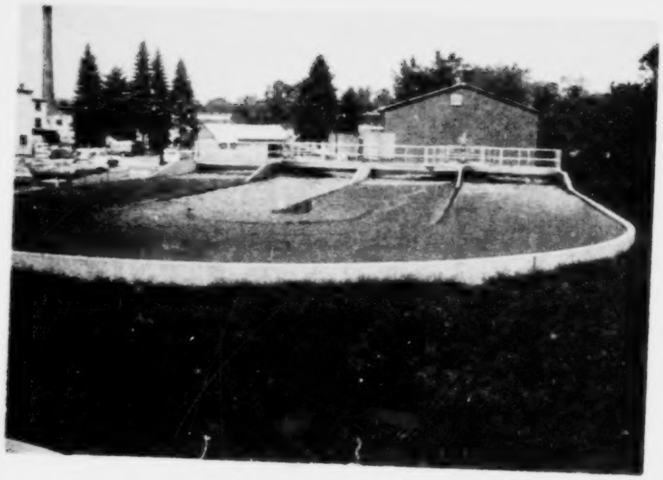


Figure 11. Schematic Diagram of Oxidation Ditch.



gure 12. Carrousel Oxidation Ditc

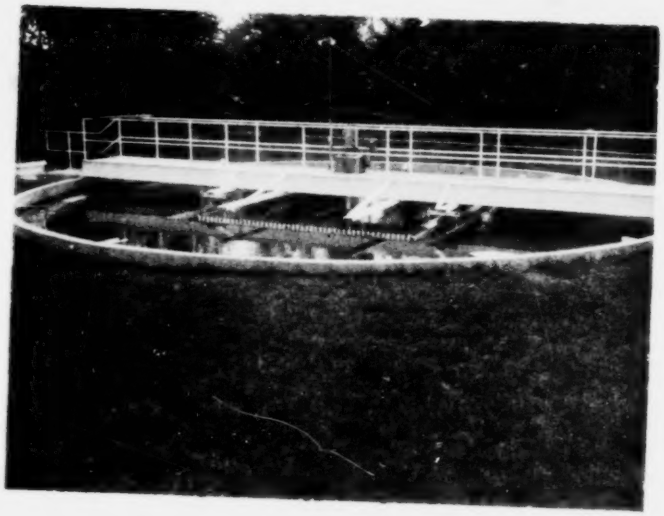


Figure 13. Final Clarifier

Aerators -

Oxygenation capacity - O_2/hp/hr (lb) - - - - - - 3.5
Design formula - $O_2 = 1.5 \times \text{BOD} + 4.6\ \text{TKN}$
Number - 2
Manufacturer - Hubert Sneek
Type 190
Diameter (mm) - - - - - - - - - - - - - - - - - - - 1900
Motorized adjustable immersion
  Minimum (cm) - - - - - - - - - - - - - - - - - 0
  Maximum (cm) - - - - - - - - - - - - - - - - - 30
Motors - Drive motors
Manufacturer - Scorch
HP - 20
Speed (rpm) - - - - - - - - - - - - - - - - - - - 1160

Immersion adjustment motors
Manufacturer - Leroy
HP - 1
Speed (rpm) - 1700

Final Clarifier

This is a rim flow clarifier with bottom sweeps directing settled solids to a collection point. It removes biological solids generated in the oxidation ditch and discharges a clear effluent to the river.

Manufacturer - Clow Corp.
  Florence, Ky.
Model - UEOFLO
Diameter (ft) - 46
Depth (ft) - 9
Operating depth (ft) - - - - - - - - - - - - - - - - 8
Feed - Peripheral
Sludge draw - Center
Effluent outlet - - - - - - - - - - - - - - - - - - - Center

Sludge Return Pumps

These pumps return solids separated from the wastewater flow in the final clarifier to the oxidation ditch, or to the sludge holding tanks as wasted.

Manufacturer - Midland Pump Co.
Model - Midwhirl No. 4WS-4511
Capacity (gpm) - - - - - - - - - - - - - - - - - - - 350
Motor HP - 30

HOUSING

All of the components of the primary section, and the solids compaction equipment are housed in a prefabricated, insulated, steel building.

Manufacturer - Butler Buildings, Inc.
Length (ft) - 104
Width (ft) - 40
Height - bottom of truss (ft) - - - - - - - - - - - - 16
Ventilation -
    Exhaust fans at gable peak, each end.
    Diameter (in) - - - - - - - - - - - - - - - - - - - 36
    Speed (rpm) - 500

SECTION 4

PRIMARY TREATMENT

Evaluation of processes for primary wastewater treatment began at Winchester in 1971. During that year, following laboratory bench-scale work, a pilot plant using electrolytic microbubbles and suspended solids flotation was designed and constructed to treat 15 gpm. The preliminary runs with this equipment were encouraging but not successful because of incomplete flotation of solids.

Modifications were made, and during the summer of 1972, preliminary test runs were repeated. These pilot tests clearly showed that the electroflotation basin alone was inadequate to give reproducible and consistently acceptable treated wastewater. Finally in 1973, an electrocoagulation cell was developed, designed, and installed just ahead of and in series with the electroflotation basin (Figure 9). This step was the key to success.

During the summer of 1974, round-the-clock runs were made operating the pilot unit at 12 gpm. These tests lasted for several weeks, and the results conclusively showed that the two-step electrocoagulation electroflotation technology could provide the results desired.

ELECTROCOAGULATION

Theory of the Electrocoagulation Process[1,2,3,4,5,6]

The key step in this primary treatment is the addition of microbubbles to the wastewater after metal coagulants have been added and before the addition of a polyelectrolyte. This step is especially important in wastewaters that have suspended material of high specific gravity (3 and higher). In the electrocoagulation cell, the surface charges on the pollutant particles are neutralized by the metal coagulant. This condition brings about a growth in aggregate size of pollutants. Under these circumstances, the high density of the pollutants invariably leads to a rapid settling action.

The notable contribution of this new two-step technology is the addition of a buoyancy factor (microbubbles) to the pollutant particles. Pairing of particles and microbubbles is enhanced either by vortex action or other turbulence, which increases the probability of collision between pollutant aggregates and microbubbles. Once the microbubble and pollutant particle have collided and united, the addition of the polyelectrolyte flocculates the solid-gas aggregate and forms a gross floc that is buoyant.

In the initial work at the A. C. Lawrence Leather Company, only electrolytic microbubbles were employed in the coagulation cell. Since that time, extensive tests have shown that dispersed air as well as dissolved air can effectively be used in the two-step process. Single-step jar tests carried out with direct-dissolved air flotation were not successful.

In summary, this two-step concept provides a useful new technology for treatment of industrial wastewater.

Dispersed-Air Coagulation Cell Versus Electrocoagulation Cell

An electrocoagulation cell employing electrolytic microbubble generation was initially the only source of flotation and was evaluated at the Winchester plant. The cell contained 126 TA-2 electrodes with a horizontal surface-to-surface spacing of half an inch. These electrodes were placed beneath the wastewater flow pattern and were situated below the coagulation cell proper. The electrolytic microbubbles generated at the electrodes rose to the center of the vortex coagulation section by natural buoyancy.

Wastewater enters and leaves the coagulation cell tangentially. The design called for the coagulation cell to use 6 to 7 V DC and to provide a DC current of approximately 3,000 A. Under these conditions, the volume of electrolytic gases generated was 30 liters/min (STP, 2.0 vol % of the wastewater treated). Microbubbles that coalesced in the coagulation cell were vented through a 3-in pipe in the center of the vortex coagulation unit.

Problems developed quite early in the electrolytic microbubble generation section. The wooden electrode supports deteriorated rather quickly, and some electrodes shorted out. Problems also occurred with wool and debris accumulation on and around the electrodes,which interfered with good bubble formation. Our consultants suggested as a remedy the use of an in-line mixer that, when properly supplied with air, could cause minute bubbles to form directly in the waste stream.

This dispersed-air generator, which is produced by Lightning Mixer (Figure 5), is housed in a 10-in. diameter pipe that is placed just before the vortex coagulation cell. Compressed air (10# psi and higher) is fed to the bottom of the mixer. Air volume is regulated in the mixer by a rotameter valve, which is adjusted for a flow of about 2 ft^3 (56.6 lt/min STP). The microbubbles generated by the dispersed-air device are definitely coarser than those generated electrolytically. A small percentage of bubbles produced by the dispersed-air device are very large, approaching 2,000 microns in diameter. These microbubbles are deleterious to the overall process and must be removed in the fractionator. This device is an open-top vessel located approximately 10 ft downstream from the vortex coagulation cell (see Figure 9). The microbubble fractionator is 3 by 3 ft and 4 ft high. Bubbles larger than a certain size (approximately 400 microns in diameter) exit from the wastewater through the fractionator. The fine bubbles, because of their slow rise rate, are held in the hydraulic flow pattern. Failure to use a bubble frationator invariably leads to poor results in the electroflotation basin, since the wastewater carries large bubbles into the flotation basin, where the turbulence they

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create breaks up the floc as it is being skimmed off.

ELECTROFLOTATION

A major component in the primary treatment system follows next in the sequence, the LectroClear flotation basin (Figure 9). The design was furnished by Swift Environmental Systems of Chicago, the holder of patents in connection with the application of this device. The flotation basin contains microbubble-producing electrodes that perform two main functions: the first is to provide assistance to stray floc agglomerates that may not have acquired enough bouyancy in the coagulation cell to help them to the surface, and the second is that as the microbubbles rise and encounter the underside of the floating sludge blanket they add bouyancy and raise the top of the blanket above the water surface. As a consequence of this action, substantial dewatering occurs through downward flow of water and the solids content of the skimmed sludge increases to as high as 10%. In actual practice, the operators say that all is well with the system when the skimmings look like wet crumbly gingerbread.

SOLIDS COMPACTION

The skimmings, which now contain nearly all of the influent suspended solids, are directed by the screw conveyor on the LectroClear flotation basin to a transfer pump and thence into storage tanks to await charging into the filter press during the normal working day. They are withdrawn from the storage tanks by means of an air-actuated diaphragm pump called a Sand Piper, which is particularly efficient for this purpose. At the end of the charging cycle, the pump is working at 100 psi and thus creates a very solid cake in the press. Filtration and compaction are enhanced by raising the temperature at 150° F or so, hence the inclusion of a heat exchanger between the Sand Piper and the filter press.

OPERATION OF THE PRIMARY SECTION

The plant obtains about 90% of its water for processing from the Ashuelot River. City water is used for drinking and for certain limited plant processing steps. Dumping of the water used for processing the pelts occurs between the hours of 3 a.m. and 7 p.m., with the peak hydraulic wastewater flow occurring at about 11:00 a.m. As the wastewater leaves the plant, it passes through a stainless steel, cylindrical Stehling screen where some of the wool fiber is removed. From this point, the water passes into a 3,000-gal pit and is then pumped directly into the 170,000-gal holding tank. Wastewater in the holding tank is lifted by an immersion pump and passes through a head box that provides the hydraulic head to feed the primary LectroClear operation. This hydraulic head provides a flow of about 300 gpm, and the wastewater flows by gravity from the headbox to and through the entire primary phase.

When the wastewater leaves the head box (in a 10 in. pipe), 1,000 mg/l of alum is added. At a distance of approximately 20 ft from the alum addition and just before the dispersed-air device, 800 ppm of hydrated lime is added from a 10 wt% lime slurry. Both chemical additions are added by metering pumps manually set to a predetermined feed. The wastewater then passes through the dispersed-air device and the vortex coagulation cell for a dwell time of 2.2 min, after which 12 mg/l of polyelectrolyte is added (X-400 Swift anionic polyacrylic acrylamide). At this point, the pH is consistently between 7.5 and 8.5. The pH is monitored frequently, and deviations from the just-above-neutral zone are corrected by adjustment to the lime-feeding mechanism.

The intention was to control pH by automatic adjustment of lime feeding. Equipment was provided for this at the outset, but thus far, manual adjustment has not only been found to be adequate, but more reliable.

The system is designed as an on-off operation. This on-off control is carried out by a float switch in the holding tank. When the water in the holding tank is above a predetermined level, the float switch keep all pumps and power on. Conversely,when the water is below a certain level, it keeps all pumps and power off.

SECTION 5

SECONDARY BIOLOGICAL TREATMENT

OXIDATION DITCH [7,8,9,10,11,12,13]

The secondary wastewater treatment process consists of biological reduction using an oxidation ditch of proprietary design known as a CARROUSEL,™ and a rim flow clarifier.

The carrousel concept was first applied to sewage treatment in 1968 at Oosterwolde, Netherlands. Today more than 100 carrousel installations are in operation. Capacities range up to 300 mgd flow with 500 to 600 mg/l BOD. Dairy, food, tannery, brewery, chemical, pharmaceutical, and paper industry wastes have all been treated. The first carrousel installation in the United States went on line in December 1976 at the A. C. Lawrence Leather Company, at Winchester, N. H.

The carrousel is a technical modification of the original oxidation ditch developed during the 1950's by Dr. Ir. A. Pasveer of the Netherlands Research Institute for Public Health Engineering, Delft, Holland. Several thousand of these oxidation ditches are in operation worldwide. Aeration in the original ditches was supplied by horizontally mounted cage rotors, whose oxygenation rates and amounts depended on the rotor design, immersion depth, and the rpm.

The extended aeration process used in most oxidation ditches yields a high percentage of BOD, COD, and suspended solids reduction and a sludge that has been aerobically digested. The latter is a result of the endogenous respiration phase undergone by microorganisms.

The carrousel concept was developed and patented by Dwars, Heederik en Verhey, B.V., Amersfoort, Holland -- a European consulting firm. It is a hydraulic application of vertically mounted mechanical aerators that impart oxygen and that simultaneously provide sufficient horizontal velocity to prevent solids from settling in the aeration channels. Final settling tanks are the only major components needed in addition to the aeration channels for most applications. Settled sludge is returned to the aeration unit, with excess sludge being wasted periodically.

The number of aerators and the size are based primarily on the amount of oxygen needed. In turn, the channel cross-section dimensions are based on the aerator impeller size. The channel length is a function of the volume, which is related to the treatment efficiency or the type of activated sludge process selected. Special shaping is used to optimize the velocity. The platform or bridge must be designed to handle all of the forces and vibrations associated with the aerator. See Figure 11.

The common design factors or criteria required to produce a BOD reduction of 95% to 99% and a COD reduction of 90% to 95% are as follows:

a. Mixed liquor suspended solids (MLSS) (mg/l) - - - - - 5000 to 6000
b. Organic loading (lb BOD/lb MLSS/day) - - - - - - - - - 0.05 to 0.10
c. Oxygen supply (lb/lb BOD) - - - - - - - - - - - - - - - 2.0 to 2.5
d. Hydraulic volume (ft^3/lb BOD) - - - - - - - - - - - - - 80

The carrousel can be operated to achieve nitrogen removal without additional treatment units and without the use of chemicals for a carbon source. Thorough nitrification is achieved by large numbers of nitrifying organisms maintained in the aeration unit. The high MLSS, the long retention time, and the well-conditioned sludge are all conducive to good nitrification.

After the organic nitrogen has been oxidized to nitrate, denitrification is accomplished by specific strains of organisms in the carrousel. A section of the channels is made to operate at or near zero DO(0 to 0.5 mg/l), thus creating a favorable environment for denitrifying bacteria. This may be accomplished by automatic control of the dissolved oxygen concentration at the aerators by using a DO probe and instrumentation that can activate a mechanism to change the depth of immersion and thereby the rate of oxygenation; or by manual depth adjustment. The mixed liquor is passed through this anoxic zone, in which an adequate carbon source is available from the continual inflow of raw waste, during which denitrification takes place. This phase lasts only a few minutes, as the velocity in the channel normally exceeds 1 fps. Odor problems do not develop because of stable sludge condition as well as the very short time period in the anoxic zone for each pass. An advantage of combining oxygenation and denitrification in the design is the release of oxygen during denitrification for BOD removal.

The interconnection of DO probes and instrumentation with the aerators to allow the automatic monitoring of DO levels to control immersion depths of the aerators on this carrousel has not been successful to date. Since this was a design feature A. C. Lawrence has, on several occasions, attempted to derive satisfaction on this point from the licensor, but as of the close of this demonstration period the control of immersion depths is manual.

FINAL CLARIFIER

A high content of suspended solids (7000 to 8000 mg/l) is generated in the carrousel through bacterial activity. This material must be removed before the wastewater flow can be released to the river. A rim flow clarifier is used for this purpose having a maximum solid flux design load of 1.0 lb/ft^2 per day, and peak flow limited to 600 gal/ft^2 per day. Suspended solids removed by this clarifier are continuously returned to the carrousel or wasted to the sludge holding tanks for a period each day.

OPERATION OF THE SECONDARY

Dissolved Oxygen Control.

The measure of dissolved oxygen at the aerators is used to control the biological activity and operating efficiency of the carrousel. The operator uses a portable DO meter for this purpose, taking readings at least daily, and more often if necessary or desired, just downstream from aerators one and two. Aerator one is designated as the unit nearest the discharge point, and since this is next adjacent to the anoxic zone it is required to furnish oxygen to the greater degree.

The operating goal is to maintain a level of 1.5 mg/l of dissolved oxygen at aerator one and about 1.0 mg/l at aerator two, with residuals of 0.5 at the section of the carrousel farthest from the aerators, and at or near zero at the discharge point. See Figure 11.

Since dissolved oxygen is almost if not non-existent in the wastewater stream as it emerges from the carrousel it is necessary to substantially raise the DO before discharge to the river. Stream requirements call for a minimum of 4 mg/l. This is accomplished with four waterfalls, each with a free fall of about three feet. The first is at the carrousel discharge overflow weir, the second is at the overflow weir at the final clarifier, and the third and fourth are arranged between the final clarifier and the river. Through these waterfalls the stream specification for dissolved oxygen as required by the State of New Hampshire is satisfied.

Suspended Solids - Activated Sludge

Mixed liquor suspended solids (MLSS) and mixed liquor volatile suspended solids (MLVSS) are sampled and analyzed at least weekly at sample point S_3. These are indicative of the biological activity in the carrousel. It is desired to maintain the MLSS at 7000 to 8000 mg/l and the MLVSS at 60 to 65% of MLSS.

Since the wastewater passing from the primary treatment section to the secondary treatment section (carrousel) is relatively free from suspended solids the high analytical values for MLSS and MLVSS are the result of biological activity. These solids are removed in the final clarifier. They are continuously completely returned to the carrousel except for a period each day when a portion is wasted into the sludge holding tanks to be concentrated in the filter press and directed to land-fill. The time of wasting each day is dictated by the actual level of MLSS at S_3 compared with the desired operating concentration. It is usually about four hours.

Phosphorus

Phosphorus is nutritionally required for vigorous bacterial life support. It is found in relatively large concentrations in the Winchester tannery wastewater, amounting to as much as 20 mg/l. The chemicals used in primary treatment, principally alum and lime, remove or combine with some of the phosphorus, however, making it mostly unavailable as a nutrient for the bacteria in the secondary treatment section. The accepted nutrient ratio of 100 BOD to 5 nitrogen to 1 phosphorus for good bacterial growth indicates that, for every 100 parts of BOD treated, one part of phosphorus must be available.

At this treatment plant the mean BOD loading to the biological section is 280 mg/l or an average of 700 to 800 pounds per day. On this basis the daily addition of 2 gallons of 75% phosphoric acid, containing approximately six pounds of phosphorus as P, in addition to the residual available in the flow to the secondary, was dictated. The resulting BOD reductions and other manifestations of biological activity demonstrated that the amount was sufficient. The phosphorus content in the final effluent is low, usually 5 mg/l or less, indicating good balance of biological usage and chemical absorption.

Foam and Foaming

When the plant started operation in December, 1976, foaming on the oxidation ditch was extensive. Anti-foaming agents were considered, but as the MLSS increased the foaming decreased. As the MLSS approached design foaming was no longer present.

SECTION 6

EXPERIMENTAL PROCEDURES

SELECTION OF PARAMETERS

Soon after this demonstration project was approved and accepted by E.P.A. a meeting was held at Winchester at which all of the principals of the program were present, including the project officer, the project director, the consultants, and local operating personnel. Data collection and analysis were discussed in detail. The parameters considered essential are listed in Table 2, along with where and how the samples for them should be taken. In addition to those listed a number of daily measurements and readings were specified which would be needed to properly assess the performance and allow operating costs to be calculated. These were:

Pelts processed
Lime consumed
Alum consumed
Polymer consumed
Electricity consumed
Dissolved oxygen at aerators one and two
Depths of the top of the sludge blanket in the final clarifier
Primary sludge volume
Secondary sludge volume wasted
Outside temperature

Values for all of the parameters and readings for the special periods of this project are given in Section 7, Tables 6, 7, 8, and 9. The absence of chemical oxygen demand (COD) as an analytical parameter and measure of performance will be noted throughout this report. The high concentration of chloride in the waste stream, unchanged during the treatment process, interfered with the analytical procedure to such a degree as to render the determination useless.

SAMPLING PERIODS

Activated sludge operations are temperature-dependent, and most full-scale wastewater treatment systems are expected to reduce BOD more efficiently in summer than in winter. The claimed superiority of the carrousel design in this respect prompted a large share of the interest in this project. A special condition for data collection and analysis was set forth in a grant amendment dated August 23, 1976. This condition was:

> The sampling and data collection procedure in part IV-e of the proposal shall:

TABLE 2. LABORATORY DATA REQUIRED FOR EPA PROJECT

Parameter	Equalized influent S_1	Primary effluent S_2	Carrousel effluent S_3	Final effluent S_4	Return sludge S_5	Primary sludge S_6	Dewatered sludge S_7
Dissolved oxygen			D				
BOD_5	D**	D		D			
Solids-total	O			O**			O
-Suspended	D	D	D	D	O	O	
-volatile		D	D				
-Settleable			D				
pH	D	D		D			
Fats, oils, grease	D	D		D			O
Nitrogen-Ammonia	D			D			
Kjeldahl	D	D		D			O
Nitrite				D			
Nitrate				D			
Phosphorus-Total				D			
Chromium-Cr	D	D		D			O
Fecal Colifonn				D			
Flow	D				D		
Temperature °C	D		D				
Chloride	O*			O			
Sample Type	G*	C	G*	G*	G	G	G

* 2 hour intervals during working day

** Frequency D - Daily O- Occasionally

> ---be performed on not less than 25 days of typical operation during the winter and on not less than 25 days of typical operation during the summer.

At the time of selection of parameters and data readings it was established that operating temperatures for mixed liquors would be limited to a minimum of 21°C for summer operating conditions, and a maximun of 16°C for winter. On eight occasions during the winter this rule was violated slightly, particularly toward the end of the operating week, when the warm wastewater from the tannery was sufficient to offset atmospheric cooling. The average temperature recording in the carrousel at S_3 during the winter period was 15.6°C. This result demonstrates the innate resistance of the carrousel to atmospheric interference, since the average of the outside highs and lows was minus 8.8, and the lowest low minus 26°C.

SAMPLING

The following procedures were used for procuring samples at sample points S_1 through S_4. See Figure 1.

S_1 - wastewater from the holding and equalizing tank. This is also called raw wastewater in this report.
Four 1 liter grab samples were taken from the tank at approximately 2-hr intervals. These were refrigerated, and composited at the end of each day.

S_2 - effluent from LectroClear primary treatment. An Isco sampling instrument was used. Ice was employed in the instrument. The device was programmed to sample 10 ml every 15 min.

S_3 - grab samples taken at the discharge overflow weir of the carrousel. These were taken four times a day at about equal intervals, refrigerated, and composited at the end of each day.

S_4 - grab samples taken after discharge from the final clarifier four times a day at about equal intervals, refrigerated, and composited.

ANALYTICAL METHODS

The analytical methods used were those specified in:

Methods for Chemical Analysis of Water and Waste 1976
U.S. Environmental Protection Agency

FREQUENCY OF ANALYSES

Since two periods of intensive sampling were specified for this project, 25 days of summer conditions and 25 days of winter conditions, sampling and analysis were performed five days each week for five consecutive weeks beginning September 12, 1977, and for 25 working days of seven consecutive weeks beginning December 12, 1977, and extending into February, 1978.

PERFORMANCE OF ANALYSES

Routine weekly analyses have been performed in the laboratory at the Winchester wastewater treatment plant since start-up. This routine was not interrupted during the demonstration periods.

Since daily analyses are not feasible in the on-plant facility most of the analytical work for this project was performed by Tighe and Bond, a certified and approved laboratory located at Easthampton, Mass. Composite samples from sampling points S_1, S_2, S_3, and S_4 were delivered by A. C. Lawrence personnel to Tighe and Bond each day on the day they were obtained.

It will be noted in reviewing the tables of analytical data, and the graphs, that analysis was not made for every parameter at all four sampling points. Those not showing were considered by the project officer and consultants to have insufficient significance to be included.

QUALITY CONTROL

Two approaches to quality control of analytical work were used.

The first was the analysis of identical samples by the A. C. Lawrence laboratory and by Tighe and Bond. Composites from each of the sampling points S_1, S_2, S_3, and S_4 were divided on three separate days, one portion going to each laboratory. The results are presented in Table 3. Examination of the comparative values reveals very few instances of unsatisfactory agreement. A. C. Lawrence results were consistently higher for nitrite in the final effluent, and one Tighe and Bond analysis for fats, oils and grease was so high as to be technically suspect. Otherwise there were no deviations between laboratories in excess of standard.

The second approach was the furnishing of standard samples by the U.S.E.P.A. Industrial Environmental Research Laboratory to the A. C. Lawrence laboratory at Winchester. The samples were received in May, 1978. Results by A. C. Lawrence were reported early in July. The values reported and the values provided by E.P.A. for the standard samples are presented in Table 4. The agreement was generally good. A critique of this effort prepared by the Project Officer is presented as Appendix A.

The third quality control measure was the analyzing of samples in duplicate in the treatment plant laboratory. These analyses are presented in Table 5. The agreement is good for all parameters.

PRESENTATION OF DATA

No statistical analysis of data has been attempted. All analytical determinations as presented in the tables are as reported by the analysts. In some cases inconsistencies occur, such as ammonia nitrogen in excess of kjeldahl nitrogen in the same sample. These are considered to be within the experimental error.

TABLE 3. ANALYTICAL LABORATORY QUALITY CONTROL
COMPARISON OF RESULTS ON DIVIDED SAMPLES

Sample	BOD_5 (mg/l)			Suspended Solids (mg/l)				Volatile suspended Solids (mg/l)		Fats, oils Grease (mg/l)		
Date	S_1	S_2	S_4	S_1	S_2	S_3	S_4	S_2	S_3	S_1	S_2	S_4
9/14/77												
A. C. Lawrence *	960	131	5	670	141	8,360	30	105	5,010	539	32	8.8
Tighe and Bond **	990	262	4	828	150	9,280	32	126	5,550	401	33	5.4
10/12/77												
A. C. Lawrence	870	366	7	1,104	410	9,730	64	868	6.750	454	82	0.8
Tighe and Bond	790	347	6	1,005	412	8,669	13	905	5,205	480	101	18.0
12/12/77												
A. C. Lawrence	988	366	6	1,070	135	11,362	19	76	7,120	548	37	5.5
Tighe and Bond	980	324	7	992	194	12,360	68	102	7,610	559	22	3.2

	Ammonia N (mg/l)		TKN (mg/l)			Nitrite (mg/l)	Nitrate (mg/l)	Chromium Cr (mg/l)		
	S_1	S_4	S_1	S_2	S_4	S_4	S_4	S_1	S_2	S_4
9/14/77										
A. C. Lawrence	25	0.50	104	47	3.9	.750	34.5	82	7.9	1.01
Tighe and Bond	32	0.47	73	44	3.1	.180	40.1	70	5.5	0.81
10/12/77										
A. C. Lawrence	39	1.44	76	52	4.5	.640	8.5	95	28.	0.45
Tighe and Bond	40	2.70	81	56	5.6	.295	9.9	110	39.	0.74
12/12/77										
A. C. Lawrence	41	2.70	91	42	5.3	.610	13.3	120	11.9	0.60
Tighe and Bond	31	1.86	82	56	4.2	.164	14.8	115	9.5	0.61

* Treatment plant laboratory
** Commercial laboratory

TABLE 4. ANALYTICAL LABORATORY QUALITY CONTROL COMPARISON OF RESULTS BETWEEN A. C. LAWRENCE AND E.P.A. I.E.R.L.

Parameter	Sample number	A.C. Lawrence value	E.P.A. I.E.R.L. value or comment
BOD_5	1	20.9	within one standard deviation
	2	94	about 40% low
COD	1	74	within one standard deviation
	2	234	within one standard deviation
Ammonia-N	3	3.08	2.6
		8.96	8.8
TKN	5	5.04	2.1
	6	38.08	38
Nitrate-N	3	.925	1.2
	4	6.46	6.7
PO_4-P	3	.066	.13
	4	1.43	2.4
Total - P	5	0.906	0.85
	6	4.30	4.28
Chromium-Cr	7	11.6	within one standard deviation
	8	82.65	within one standard deviation
	9	368.3	within one standard deviation

TABLE 5. ANALYTICAL LABORATORY QUALITY CONTROL COMPARISON OF RESULTS ON SAMPLES RUN IN DUPLICATE*

Sample Date	BOD_5 (mg/l)	Suspended Solids (mg/l)				Volatile suspended Solids (mg/l)		Fats/oils grease(mg/l)	NH_3-N (mg/l)		TKN (mg/l)
	S_4	S_1	S_2	S_3	S_4	S_2	S_3	S_4	S_1	S_4	S_4
10/5/77 A	3.41	739	233	8,787	31.0	128	5,339	18	32	0.9	5.04
10/5/77 AA	3.25	725	223	8,990	31.1	128	5,220	27	32	0.9	4.48

	Nitrite NO_2(mg/l)	Phosphate PO_4 (mg/l)	Chromium Cr (mg/l)		
	S_4	S_4	S_1	S_2	S_4
10/5/77 A	0.521	0.913	75.4	2.49	1.21
10/5/77 AA	0.525	0.916	76.6	2.51	1.06
12/28/77 A	0.091				1.95
12/28/77 AA	0.096				1.94

* Treatment plant laboratory

SECTION 7

OPERATING AND ANALYTICAL DATA

DISCUSSION

In connection with this special demonstration project two separate test periods were selected, one in summer, one in winter, during which samples were taken frequently, for most of the time daily, and analyzed by an outside laboratory. Analytical results for those periods are recorded in Table 8 and Table 9.

During the entire period that this treatment plant has been in operation samples at each of the significant sampling points have been obtained at least weekly, with few exception, and analyzed by the staff analytical technician. Those results are presented in Table 10.

Thus three groups of analytical data have been accumulated from which conclusions as to system capability can be derived.

Graphs of analytical results.

In order to more clearly show the levels and trends of parameter incidence and removals across the treatment system a number of graphs have been plotted. These follow as Figures 14 through 41. Parameters plotted are:

BOD_5 (lb/day)
pH
Temperature (^oC)
Food to microorganism ratio in the carrousel
Sludge age (days)
Mixed liquor suspended solids (mg/l)
Mixed liquor volatile suspended solids (mg/l)
Sludge volume index
Suspended solids (lb/day)
Nitrogen as TKN, nitrate and total. (lb/day)
Ammonia nitrogen (lb/day)
Fats, oils and grease (lb/day)
Chromium (lb/day)

Where results are shown in pounds per day a rough conversion to milligrams per liter can be made by multiplying by 0.4. This assumes a normal daily flow of 300,000 gals. The sampling locations and procedures are explained in Section 6.

TABLE 6. SUMMER OPERATING CONDITIONS

Date	Wastewater Volume (gal)	Est. Ave. Pelts Processed	Coagulants added			pH			Temp. (°C)		
			Lime**** (gal)	Alum*** (gal)	Polymer** (gal)	S_1	S_2	S_4	S_1	S_3	O.S.*
9/12/77	661,734	3,120	1,986	1,485	868	6.2	6.1	6.7	27	23	11
9/13/77	286,344	3,120	1,102	800	1,643	6.0	8.0	7.2	31	25	12
9/14/77	280,492	3,120	1,010	540	1,191	5.1	7.5	7.4	29	26	14
9/15/77	302,058	3,120	1,290	560	1,300	4.9	6.4	6.8	28	24	15
9/16/77	275,868	3,120	1,019	600	1,683	4.9	9.4	6.9	29	24	15
9/19/77	529,038	3,120	4,045	1,209	3,080	6.8	9.1	7.1	30	25	17
9/20/77	288,090	3,120	1,369	804	1,671	6.4	7.5	7.3	28	23	16
9/21/77	307,296	3,120	1,100	804	1,508	6.1	7.7	6.6	29	23	8
9/22/77	277,614	3,120	1,750	610	1,650	6.7	8.2	6.9	27	23	9
9/23/77	331,740	3,120	2,400	810	1,980	5.7	8.6	7.1	28	24	10
9/26/77	515,070	3,120	2,098	590	1,406	5.6	7.8	6.9	28	22	9
9/27/77	316,026	3,120	1,912	610	1,976	5.0	7.9	6.5	29	24	14
9/28/77	277,614	3,120	1,202	544	760	5.4	10.4	7.5	29	25	10
9/29/77	296,820	3,120	1,974	675	1,808	6.0	8.7	7.6	29	25	13
9/30/77	316,026	3,120	2,554	651	1,982	4.0	7.9	7.1	30	24	9
10/3/77	312,534	3,120	1,808	630	1,972	6.1	7.4	7.0	27	20	12
10/4/77	347,454	3,120	2,772	910	2,308	5.2	5.9	6.6	27	21	7
10/5/77	370,152	3,120	2,608	870	2,010	6.7	8.0	7.3	26	22	8
10/6/77	316,026	3,120	2,090	689	1,900	5.0	7.3	7.5	28	22	11
10/7/77	308,990	3,120	1,794	576	1,870	4.6	7.4	7.2	28	22	7
10/11/77	275,600	3,120	1,210	620	1,648	5.0	5.6	7.4	28	22	7
10/12/77	288,404	3,120	1,390	786	1,710	4.8	7.8	7.5	28	22	9
10/13/77	368,406	3,120	1,409	970	2,062	5.5	8.9	6.7	29	22	9
10/14/77	279,360	3,120	1,392	806	1,674	3.9	6.2	6.5	27	21	7
10/15/77	310,996	3,120	1,561	775	1,910	5.6	7.5	7.1	27	21	6

**** 10% Solids
*** 45% Solids
** 0.2% Solids
* Average of outside high and low

(Continued)

TABLE 6. (CONTINUED)

Date	Flotation basin		Primary sludge volume (gal/day)	Dissolved oxygen (ppm) aerator		S_3	Settling Test S_3 (ml/l)		Secondary clarifier (ft.clear)	Secondary sludge waste (gal/day)
	volts.	amps.		one	two		a.m.	p.m.		
9/12/77	7.2	1,720	6,000	1.5	2.0	No Data Ref. Table 7	640	710	4	2,400
9/13/77	7.2	1,300	4,900	4.1	3.7		900	870	3	1,920
9/14/77	7.2	1,900	4,000	3.8	3.0		890	900	3	1,200
9/15/77	7.2	1,500	5,000	2.0	OUT		550	640	5	2,400
9/16/77	7.2	1,600	4,800	3.1	3.0		910	870	5	2,400
9/19/77	7.2	1,800	7,000	3.4	2.9		870	850	4.5	2,000
9/20/77	7.2	1,700	4.700	3.4	3.0		760	710	5	2.700
9/21/77	7.2	1,600	4,200	3.3	4.7		820	810	5	2,100
9/22/77	7.2	1,600	3,900	3.0	OUT		900	850	5	2,300
9/23/77	7.2	1,700	4,200	3.4	3.0		870	900	5	2,450
9/26/77	7.2	1,600	3,900	3.9	3.4		910	870	5	2,300
9/27/77	7.2	1,600	4,400	4.5	3.3		840	810	5	2,150
9/28/77	7.2	1,400	4,000	5.0	OUT		710	680	5.5	1,975
9/29/77	7.2	1,900	3,800	2.4	1.6		590	-	1.5	4,800
9/30/77	7.2	1,700	4,000	2.6	2.0		790	790	4	2,500
10/3/77	7.2	1,700	6,000	2.6	3.4		670	810	5	3,430
10/4/77	7.2	1,900	4,000	5.7	4.9		910	890	5	2,940
10/5/77	7.2	1,700	4,400	2.6	2.3		970	870	5	5,880
10/6/77	7.2	1,700	4,700	2.6	2.4		840	840	5	3,675
10/7/77	7.2	1,600	5,160	-	-		890	880	3.5	2,500
10/11/77	7.2	1,700	4,400	-	-		850	840	5	3,400
10/12/77	7.2	1,900	5,000	-	-		850	850	4	2,900
10/13/77	7.2	1,900	6,000	-	-		940	700	3.5	2,205
10/14/77	7.2	1,900	6,100	0.9	0.5		870	860	4	-
10/15/77	7.2	1,900	4,800	-	-		850	710	4	3,000

TABLE 7. WINTER OPERATING CONDITIONS

Date	Wastewater Volume (gal)	Pelts Processed	Coagulants added			pH			Temp. (°C)		
			Lime**** (gal)	Alum*** (gal)	Polymer** (gal)	S_1	S_2	S_4	S_1	S_3	O.S.*
12/12/77	332,640	3,205	2,045	461	1,380	5.5	7.5	7.1	23	11	-5
12/13/77	269,280	3,210	1,269	199	776	5.7	6.8	7.5	24	14	1
12/14/77	285,120	3,429	1,018	430	979	6.4	8.3	7.5	26	16	-2
12/15/77	285,120	3,190	2,047	576	857	5.2	8.2	7.0	25	18	-5
12/16/77	205,920	3,510	1,288	578	801	4.6	7.7	7.4	26	18	-4
12/29/77	241,740	3,650	2,271	516	1,423	5.6	9.2	7.1	24	15	-12
12/30/77	180,540	3,773	1,820	367	1,171	4.2	7.8	7.4	24	15	-11
1/3/78	306,000	3,600	2,497	642	1,835	4.4	9.0	7.6	26	12	-10
1/4/78	264,180	3,587	2,705	657	1,683	4.7	8.8	7.2	26	15	-12
1/5/78	233,640	3,680	2,538	497	1,651	4.9	9.0	7.3	26	18	-11
1/6/78	250,272	3,625	2,576	489	1,585	4.8	8.8	7.5	28	19	-2
1/9/78	290,700	3,750	1,916	626	1,811	5.4	8.1	7.5	21	15	9
1/10/78	300,960	3,605	2,138	720	1,340	4.9	7.4	7.3	26	13	0
1/11/78	313,296	3,626	2,522	751	1,804	5.0	8.6	7.4	26	15	-14
1/12/78	-	3,450	2,388	657	1,171	5.0	8.5	7.2	27	18	-10
1/13/78	180,720	3,762	1,837	407	1,085	4.5	8.0	7.2	27	18	-5
1/19/78	306,858	3,693	2,589	706	2,277	5.2	7.3	7.1	26	15	-8
1/23/78	301,410	3,810	1,440	516	1,056	4.8	6.2	7.1	24	13	-9
1/24/78	323,136	3,830	2,522	931	1,665	5.3	8.2	7.1	25	16	-11
2/1/78	313,650	4.070	2,255	757	1,520	4.9	6.7	7.0	25	15	-13
2/2/78	91,392	3,890	601	282	518	5.6	7.5	7.0	26	17	-12
2/3/78	178,500	3,896	1,252	563	702	4.9	8.0	7.0	24	16	-12
2/6/78	317,016	3,890	2,007	595	1,534	5.1	7.8	6.8	24	13	-14
2/9/78	312,732	3,664	2,095	556	1,687	5.4	7.4	7.3	26	16	-14
2/10/78	184,212	3,903	1,570	313	1,443	4.5	7.9	7.1	26	18	-13

****10% Solids ** 0.2% Solids
***45% Solids * Average of outside high and low.

TABLE 7. (CONTINUED)

Date	Flotation basin		Primary sludge volume (gal/day)	Dissolved oxygen (ppm)			Settling Test S_3 (ml/l)		Secondary clarifier (ft.clear)	Secondary sludge wasted (gal/day)
	volts.	amps.		aerator one	aerator two	S_3	a.m.	p.m.		
12/12/77	7	1,900	9,979	1.1	.30	.20	550	625	5.0	1,800
12/13/77	7	2,000	8,078	.8	.30	.20	560	670	5.0	1,800
12/14/77	7	2,100	8,553	1.1	.50	.50	950	825	4.0	1,800
12/15/77	7	2,100	8,661	.5	.30	.10	580	600	4.0	1,650
12/16/77	7	1,900	6,177	1.2	.30	.10	820	710	4.0	900
12/29/77	7	1,800	7,252	2.0	.25	.25	700	535	5.0	1,920
12/30/77	7	1,800	5,416	2.6	.25	.30	725	750	5.0	1,920
1/3/78	7	2,100	9,180	1.2	1.10	.20	810	750	7.0	1,920
1/4/78	7	2,000	7,925	2.4	0.25	0.25	700	660	6.5	3,840
1/5/78	7	2,500	7,009	2.2	0.25	0.25	675	630	6.0	1,920
1/6/78	7	1,900	7,508	2.4	0.25	0.50	800	590	6.0	2,560
1/9/78	7	1,350	8,721	3.3	1.75	1.90	875	800	7.5	-
1/10/78	7	1,500	9,028	1.2	1.1	0.20	875	775	3.5	3,520
1/11/78	7	2,800	9,398	1.9	1.0	0.20	825	650	2.0	2,560
1/12/78	7	2,000	-	1.9	0.15	0.15	725	800	1.5	2,400
1/13/78	7	1,700	5,421	1.9	0.15	0.25	760	650	4.0	2.720
1/19/78	7	1,800	9,205	2.0	0.20	0.20	800	700	2.5	1,920
1/23/78	7	1,700	9,042	-	-	-	850	825	-	2,280
1/24/78	7	1,700	9,694	0.7	0.10	0.30	800	740	1.5	2,304
2/1/78	7	1,700	9,409	0.9	0.30	0.20	700	750	2.0	1,920
2/2/78	7	1,700	2,741	-	-	-	720	770	2.0	-
2/3/78	7	1,700	5,355	0.7	0.35	0.35	900	800	4.0	-
2/6/78	7	1,300	9,510	0.6	0.30	0.30	950	810	5.5	1,500
2/9/78	7	1,500	9,381	1.8	0.15	0.10	775	690	5.0	-
2/10/78	7	1,600	5,526	0.7	0.15	0.30	700	625	3.5	-

TABLE 8. SUMMER ANALYTICAL RESULTS

Date	BOD_5 (mg/l)			Suspended solids (mg/l)				Volatile suspended solids (mg/l)		Fats, oils grease (mg/l)			Chromium Cr (mg/l)		
	S_1	S_2	S_4	S_1	S_2	S_3	S_4	S_2	S_3	S_1	S_2	S_4	S_1	S_2	S_4
9/12/77	750	288	5	884	378	9,270	98	216	5,560	283	34	0.6	65	17.1	1.1
9/13/77	1,080	270	5	702	192	9,730	92	98	5,660	462	20	0.8	80	4.5	0.8
9/14/77	990	262	4	828	150	9,280	32	126	5,550	401	33	5.4	70	5.5	0.8
9/15/77	840	252	3	1,098	160	9,790	42	50	5,820	470	17	1.6	80	6.5	0.8
9/16/77	630	210	5	480	230	10,310	52	72	5,880	282	27	4.4	75	4.5	1.1
9/19/77	1,140	300	3	1,414	182	10,470	82	96	6,390	439	6	1.2	95	2.2	0.9
9/20/77	960	284	5	1,028	256	9,990	120	110	5,820	298	16	0.8	85	5.0	0.9
9/21/77	1,195	283	5	1,020	40	8,140	28	28	4,880	550	25	1.5	76	2.5	1.1
9/22/77	950	322	3	896	210	10,810	78	86	6,060	258	28	5.6	70	7.5	1.2
9/23/77	570	246	4	558	122	10,400	176	68	6,020	223	17	4.4	120	8.0	1.6
9/26/77	660	308	3	988	214	10,790	140	94	6,330	510	15	4.8	87	7.1	1.2
9/27/77	690	354	3	1,294	160	10,030	50	92	5,980	573	13	3.6	110	11.3	1.1
9/28/77	975	315	5	1,225	81	10,664	126	41	6.730	596	11	4.6	100	3.8	2.0
9/29/77	930	336	3	1,222	316	9,180	34	158	5,590	402	39	3.2	105	9.2	0.7
9/30/77	470	240	3	674	306	10,670	46	178	6,340	266	72	2.0	110	22.0	1.1
10/3/77	600	192	3	972	308	10,470	80	176	6,160	1,563	134	6.6	100	17.5	1.1
10/4/77	690	246	3	954	180	10,390	58	124	6,720	439	104	2.8	85	6.5	0.8
10/5/77	683	248	3	732	228	8,888	31	128	5,430	370	43	2.2	94	11.5	0.9
10/6/77	990	312	5	1,078	236	10,060	32	142	6,190	452	25	2.8	100	23.2	0.6
10/7/77	610	216	4	676	118	9,730	32	54	5,660	265	5	0.8	100	3.5	0.2
10/11/77	870	300	4	1,022	332	9,850	60	174	6,060	377	21	1.2	85	12.0	0.4
10/12/77	870	366	7	1,104	410	9,730	64	254	6,750	454	82	0.8	95	28.0	0.4
10/13/77	790	347	6	1,005	412	8,669	13	262	5,205	480	101	18.0	110	39.0	0.7
10/14/77	830	288	4	1,004	252	10,110	40	132	6,290	415	9	2.8	100	6.3	0.5
10/15/77	580	312	6	608	316	9,700	182	182	5,920	218	61	1.8	110	27.1	0.8
10/18/77	720	252	3	1,164	142	10,620	66	84	6,520	413	5	4.8	65	1.6	1.0
10/19/77	881	286	8	1,080	96	8,677	44	59	5,299	542	24	7.0	104	4.7	1.5

TABLE 8. (CONTINUED)

Date	NH_3-N (mg/1) S_1	NH_3-N (mg/1) S_4	TKN (mg/1) S_1	TKN (mg/1) S_2	TKN (mg/1) S_4	NO_2 (mg/1) S_4	NO_3 (mg/1) S_4	Fecal Coliforms* S_4
9/12/77	23	0.9	77	44	4.2	.50	9.7	4
9/13/77	13	0.5	76	43	1.4	.18	35.5	60
9/14/77	25	0.5	104	44	3.1	.20	40.0	56
9/15/77	31	0.6	80	50	4.8	.22	41.0	204
9/16/77	12	0.2	48	36	4.2	.05	45.5	36
9/19/77	42	1.2	85	52	3.4	.01	62.0	<1
9/20/77	28	0.5	88	47	3.9	.03	51.0	<1
9/21/77	38	1.0	102	55	6.2	.52	55.0	<1
9/22/77	42	0.3	92	53	3.3	.02	35.0	18
9/23/77	43	0.4	55	43	5.8	.10	2.5	100
9/26/77	35	0.4	85	52	3.4	.00	61.0	660
9/27/77	42	0.5	88	47	3.9	.51	63.0	130
9/28/77	35	0.6	102	55	6.2	.09	75.0	469
9/29/77	42	3.1	92	53	3.3	.02	66.0	<1
9/30/77	31	3.2	55	43	5.8	.02	46.0	160
10/3/77	31	0.7	71	40	3.6	.02	61.0	<1
10/4/77	34	0.4	70	35	3.1	.01	53.0	<1
10/5/77	32	0.9	73	46	4.8	1.17	48.0	7
10/6/77	24	0.4	65	20	2.0	.01	22.0	24
10/7/77	37	0.6	43	28	5.0	.76	2.5	18
10/11/77	34	0.5	79	19	2.8	.11	13.0	36
10/12/77	39	1.4	76	52	4.5	.64	9.0	30
10/13/77	40	2.7	81	56	5.6	.30	10.0	70
10/14/77	39	3.5	83	47	7.8	.00	8.0	66
10/15/77	34	3.8	44	27	8.7	.30	5.0	18
10/18/77	10	0.9	62	32	3.9	.34	23.0	12
10/19/77	36	2.4	80	43	6.7	.00	9.0	40

*Colonies per 100 ml.

TABLE 8 (CONTINUED)*

Date	Total solids mg/1		Primary Sludge % solids	Secondary Sludge % solids	Chloride mg/1		Press Cake %				Phosphate
	S_2	S_4			S_1	S_4	Solids	FOG	Cr	TKN	PO_4 mg/1
10/12/77	17,880	10,212			7,291	5,775					0.25
9/12/77			8.70								2.80
9/14/77			8.76								.25
9/16/77			6.43								4.48
9/20/77			8.08								1.30
9/22/77			7.69								0.65
9/26/77			8.29								0.00
9/28/77			8.25								1.00
9/16/77				1.66							
9/26/77				1.21							
9/14/77							21	2.07	0.59	0.45	
10/12/77							29	4.06	0.97	0.54	
10/7/77											0.50
10/12/77											0.12
10/13/77											0.00
10/19/77											0.66

*Parameters on this table required to be determined occasionally only.

TABLE 9. WINTER ANALYTICAL RESULTS

Date	BOD$_5$ (mg/l)			Suspended solids (mg/l)				Volatile suspended solids (mg/l)		Fats, oils grease (mg/l)			Chromium Cr (mg/l)		
	S_1	S_2	S_4	S_1	S_2	S_3	S_4	S_2	S_3	S_1	S_2	S_4	S_1	S_2	S_4
12/12/77	660	312	6	1,012	282	13,050	76	190	7,860	320	42	0.8	80	18.0	1.7
12/13/77	790	330	4	1,036	146	14,130	104	82	8,750	421	24	7.5	95	8.0	0.7
12/14/77	980	324	7	992	194	12,360	68	102	7,610	559	22	3.2	115	9.5	0.6
12/15/77	690	276	8	1,120	174	15,750	76	98	9,820	310	18	2.8	135	6.5	0.6
12/16/77	720	300	6	482	148	14,280	68	110	8,810	273	19	3.8	145	8.1	0.7
12/29/77	930	348	13	2,216	212	11,690	168	108	7,280	421	39	0.4	105	7.0	0.9
12/30/77	583	212	12	1,280	292	12,320	62	158	7,740	428	16	1.2	135	11.0	1.1
1/3/78	680	272	5	1,120	342	13,280	100	156	8,300	444	16	2.0	115	6.0	1.0
1/4/78	1,067	355	7	794	151	11,130	39	82	7,060	550	36	10.0	131	6.7	1.2
1/5/78	690	312	7	1,760	330	15,040	158	100	9,030	527	15	0.8	100	17.0	0.9
1/6/78	630	288	11	1,890	348	13,990	90	140	8,700	463	9	1.8	80	1.7	0.8
1/9/78	510	276	3	1,270	186	10,100	46	118	6,640	215	26	2.6	75	8.0	0.7
1/10/78	990	360	4	1,830	320	13,750	152	186	8,780	614	34	2.2	85	10.0	0.6
1/11/78	1,258	437	7	1,060	159	10,880	16	101	7,080	685	56	1.8	126	7.6	0.5
1/12/78	1,100	432	6	1,790	336	14,070	114	170	8,600	525	42	2.0	100	7.0	0.3
1/13/78	990	372	11	1,300	280	21,640	214	158	14,180	224	52	1.0	105	6.0	0.4
1/19/78	1,020	372	4	1,520	200	13,400	66	108	8,230	579	29	4.0	95	7.0	0.3
1/23/78	930	479	3	1,320	732	13,740	110	262	8,780	375	23	3.2	85	15.0	0.4
1/24/78	990	420	10	1,330	310	19,680	92	166	12,710	320	69	5.1	100	8.0	0.35
2/1/78	1,222	434	9	1,100	248	11,640	25	175	7,800	620	77	2.3	99	11.0	0.55
2/2/78	690	408	12	1,510	298	13,110	50	216	8,680	554	60	2.6	95	10.0	0.50
2/3/78	630	456	20	1,200	406	14,620	74	256	9,660	464	90	6.8	100	18.0	1.15
2/6/78	720	444	4	1,800	438	14,690	38	306	9,550	438	92	3.0	115	16.0	0.106
2/9/78	750	348	12	1,650	476	5,340	62	292	460	575	73	3.4	125	5.0	0.60
2/10/78	720	252	20	1,380	236	13,590	46	114	8,730	536	34	3.2	110	22.0	0.55

TABLE 9. (CONTINUED)

Date	NH_3-N (mg/l) S_1	NH_3-N (mg/l) S_4	TKN (mg/l) S_1	TKN (mg/l) S_2	TKN (mg/l) S_4	NO_2 (mg/l) S_4	NO_3 (mg/l) S_4	Fecal Coliforms* S_4
12/12/77	15	0.6	46	31	0.6	.02	0.44	28
12/13/77	29	0.4	68	43	0.4	.01	0.44	4
12/14/77	31	1.9	82	56	1.9	.16	1.48	40
12/15/77	18	5.5	86	62	5.5	.01	0.44	110
12/16/77	44	9.3	72	51	9.3	.63	0.62	7,000
12/29/77	27	4.5	95	60	4.5	.00	0.44	<1
12/30/77	37	12.4	62	46	12.4	.12	0.89	20
1/3/78	33	0.0	79	52	0.0	.00	3.30	430
1/4/78	37	7.0	78	53	7.0	.05	0.51	148
1/5/78	32	13.4	81	58	13.4	.03	0.00	<1
1/6/78	37	15.5	64	43	15.5	.04	3.50	<1
1/9/78	5	0.0	61	35	0.0	.03	3.70	40
1/10/78	25	5.8	71	45	5.8	.14	1.30	220
1/11/78	43	3.7	105	65	3.7	.04	0.33	368
1/12/78	68	6.1	88	61	6.1	.02	0.00	2,600
1/13/78	33	16.7	59	45	16.7	.03	1.10	2,800
1/19/78	29	5.5	87	52	6.7	.32	18.20	110
1/23/78	37	1.2	79	50	1.4	.03	5.30	4
1/24/78	24	15.5	89	58	15.7	.01	9.60	4
2/1/78	44	16.0	85	55	14.0	.019	0.13	168
2/2/78	20	7.5	70	41	21.0	.010	0.00	4
2/3/78	46	10.0	67	52	23.0	.006	0.62	4
2/6/78	30	1.4	85	28	1.7	.002	1.60	2
2/9/78	27	16.2	72	52	16.8	.030	0.44	2
2/10/78	31	28.0	63	44	30.0	.000	0.44	2

* Colonies per 100 ml.

TABLE 9. (CONTINUED)

Date	Total solids mg/l S$_2$	Total solids mg/l S$_4$	Primary Sludge % solids	Secondary Sludge % solids	Chloride mg/l S$_1$	Chloride mg/l S$_4$	Press Cake % Solids	Press Cake % FOG	Press Cake % Cr	Press Cake % TKN	Phosphate PO$_4$ mg/l
11/30/77	17,000	13,000			7,870	6,736					0.00
12/14/77	15,000	12,000			6,523	6,346					0.00
12/12/77			6.25								0.15
12/14/77			8.00								0.21
12/16/77			6.17								0.29
12/19/77			7.89								0.20
1/3/78			7.55								0.00
1/6/78			6.90								0.03
1/10/78			7.94								0.00
1/11/78			7.07								1.43
1/12/78			6.79								0.11
2/6/78			7.49								0.20
2/8/78			7.42								4.34
12/15/78				1.43							
1/23/78				1.34							
11/30/77							33	3.84	0.98	0.57	
1/12/78							34	4.15	1.26	0.41	

TABLE 10. FIRST SIXTY WEEKS ANALYTICAL RESULTS

Week No.	Day Sampled	Volume mgd	BOD$_5$ lb/day			Suspended Solids lb/day			MLSS lbs	Sludge Age	Chromium Cr lb/day		
			S_1	S_2	S_4	S_1	S_2	S_4	S_3	Days	S_1	S_2	S_4
1	12/21/76	.306		816	128		388					4.08	
2	12/28/76	.317	1,465	785	127	2,456	315	299	8,580	12	111.0	5.08	
3	1/4/77	.295		787	96		249	313	9,813	13		2.95	
4	1/11/77	.319		782	154		72	346	7,621	11		2.66	
5	1/18/77	.344		1,248	207		668	215	15,428	15		19.22	
6	1/25/77	.287	1,654	771	136	1,360	84	237	11,780	15	67.0	1.80	6.22
7	2/1/77	.355		953	89		186	175	12,448	16		3.55	3.85
8	2/8/77	.295		814	91		145	86	11,940	15		6.27	1.67
9	2/15/77	.286		935	86		262					8.11	4.84
10	2/22/77	.305			51			74	12,905				2.04
11	3/1/77	.287			48			41	13,940				1.96
12	3/8/77	.321			59			67	18,108				.94
13	3/15/77	.321		1,205	32	6,409	112	27	15,473	14	324.		1.34
14	3/22/77	.267	1,505		74	3,630	203	71	18,935		200.		1.83
15	3/29/77	.276		1,004	48	4,553	470	90	15,831	15	262.		2.07
16	4/5/77	.377	3,908	1,185	47	4,968	164	98	21,210	24	277.		3.08
17	4/12/77	.283	2,948	1,393	18	4,617	843	25	19,766	14	250		.97
18	4/19/77	.272	2,386	1,352	25	3,425	1,520	61	24,899	18	220		1.84
19	4/26/77	.269	3,237	1,452	40	4,871	1,873	63	27,630	18	272		2.60
20	5/3/77	.312	3,438	942	36	4,080	403	47	27,279	22	234		2.60
21	5/10/77	.295	2,296	861	17	3,959	635	18	20,251	24	249		1.11
22	5/17/77	.316	3,874	1,062	32	4,451	182	42	24,921	26	226		1.93
23	5/24/77	.304	3,537	1,407	12	4,881	1,039	15	29,547	22	284		.98
24	5/31/77	.336	3,221	869	10	4.777	219	38	25,551	32	266		1.65
25	6/7/77	.313											
26	6/14/77	.241											
27	6/21/77	.313	2,584	848	15	3,216	405	17	25,273	33	201		.47
28	6/28/77	.376	3,057	1,151	34	3,920	643	27	27,148	31	229		1.10
29	7/5/77	.343	2,303	1,459	14	3,753	1,799	29	26,959	22	226	62.9	1.09
30	7/12/77	.364	2,313		14			49	26,151				.85
31	7/19/77	No Data											

TABLE 10. CONTINUED

Week No.	Day Sampled	Volume mgd	BOD$_5$ lb/day S_1	BOD$_5$ lb/day S_2	BOD$_5$ lb/day S_4	Suspended Solids lb/day S_1	Suspended Solids lb/day S_2	Suspended Solids lb/day S_4	MISS lbs. S_3	Sludge Age Days	Cr Chromium lb/day S_1	Cr Chromium lb/day S_2	Cr Chromium lb/day S_4
32	7/26/77	No Data											
33	8/2/77	.363	2,516	730	10	2,604	109	38	26,857	47	294	5.5	2.82
34	8/9/77	.325	2,098		11	2,971	2,567	51	32,096		293	141.0	2.98
35	8/16/77	.366	1,758	861	11	3,724	1,774	62	29,170	43	369	79.4	2.05
36	8/23/77												
37	8/30/77	.342	918	391	16	3,195	231	185	24,538	75	251	22.5	6.85
38	9/6/77	.287			10	1.972	311	96	24,819	38		10.5	3.83
39	9/13/77	.231	1,850	252	10	2,487	524	112	26,704	85	158	15.2	1.9
40	9/20/77	.307	3,060	737	13	6,688	261	184	26,001	38	195	6.4	2.8
41	9/27/77	.278	2,261	730	12	6,585	436	677	34,063	45	232	8.8	4.6
42	10/4/77	.370	2,108	765	9	6,971	2,172	296	28,390	48	290	35.5	2.8
43	10/11/77	.288	1,898	834	14	5,798	2,378	75	27,691	33	264	93.7	1.7
44	10/18/77	.313	2,300	747	21	7,359	655	300	27,716	41	271	12.3	3.9
45	10/25/77												
46	11/1/77	.250			6			67					1.77
47	11/8/77	.283			50			113	29,150				2.36
48	11/15/77	.325			18			108	30,754				2.63
49	11/22/77	.260			9			52	35,871				1.30
50	11/29/77	.266			33			35	38,985				2.38
51	12/6/77	.261			21			70	36,909				1.94
52	12/13/77	.285	2,348	870	15	2,543	321	45	36,293	41	285	27.8	1.50
53	12/20/77	.356	2,366	846	10	1,678	229	59	36,734	54	288	22.3	1.19
54	12/27/77	.242	1,877	702	26	4,473	428	339	37,340	71	211	14.1	1.82
55	1/3/78	.264	2,349	782	15	1.748	333	86	35,552	61	289	14.8	2.64
56	1/10/78	.313	3,284	1,141	18	2,767	415	42	34,753	40	329	19.8	1.31
57	1/17/78	.307	2,611	953	10	3,892	512	169	42,803	60	243	17.9	0.77
58	1/24/78	.323	2,667	1,131	27	3,583	835	247	62,862	74	269	21.6	0.94
59	1/31/78	.314	1,964	911	31	2,880	650	66	37,181	54	259	28.8	1.44
60	2/7/78	.313	1,958	908	31	4,307	1,243	162	17,057	25	326	13.1	1.57

TABLE 10. CONTINUED

Week no.	Day Sampled	Fats, oils, and grease lb/day			Kjeldahl - N lb/day			Nitrate - N lb/day	Total-N lb/day	Ammonia-N lb/day		Temperature °C	pH
		S_1	S_2	S_4	S_1	S_2	S_4	S_4	S_4	S_1	S_4	S_3	S_3
1	12/21/76		80.6										
2	12/28/76	1,190	55.0									11	
3	1/4/77		39.4									8	7.4
4	1/11/77		77.2									9	7.4
5	1/18/77		200.8							104		12	7.7
6	1/25/77	833	43.1							95		13	7.3
7	2/1/77		45.9							67		12	7.4
8	2/8/77		66.4							121	118.4	11	7.3
9	2/15/77		116.9							89	96.0	11	7.7
10	2/22/77		78.4							88	73.9	13	7.4
11	3/1/77			31.1							61.1	17	7.5
12	3/8/77			16.1							43.1	16	7.4
13	3/15/77	2,241	45.5	16.1							56.2	17	7.6
14	3/22/77	1,336	98.0	24.5				.62		62	32.1	17	7.3
15	3/29/77	1,754	198.0	54.7				.22		87	66.8	15	3.2
16	4/5/77	196	66.0	23.6				.41		97	55.2	21	7.8
17	4/12/77	1,879	455.5	7.1	352	157	59.7			120	66.0	17	7.2
18	4/19/77	1,361	453.7	13.6	342	137	66.1	.21	66.3	97	73.2	19	3.5
19	4/26/77	1,745	540.7	33.7	206	152	81.7	.45	82.2	93	81.7	21	7.5
20	5/3/77	1,859	124.9	46.8	424	168	69.6	.74	70.3	97	65.1	20	7.7
21	5/10/77	1,274	179.6	27.1	234	130	72.9	.91	73.8	81	62.5	22	7.5
22	5/17/77	1,950	23.7	23.7	199	128	81.2	.25	81.5	98	81.2	19	7.6
23	5/24/77	1,643	329.6	17.7	250	111	94.9	.26	95.2	103	94.9	25	7.7
24	5/31/77	1,728	62.7	5.2	241	140	81.3	.06	81.4	122	75.7	28	7.4
25	6/7/77	No Data			214	97	74.4	.28	74.7	157	70.3	25	8.1
26	6/14/77	No Data											
27	6/21/77	1,201	138.4	32.4									
28	6/28/77	1,455	235.2	8.2	170	107	33.9	.26	34.2	73	27.4	26	7.7
29	7/5/77	1,242	489.2	45.8	207	116	42.0	.19	42.2	74	47.0	28	7.4
30	7/12/77			9.1	237	169	37.2	.54	37.7	100	24.3	25	7.4
31	7/19/77	No Data					18.8	.94	19.7		4.6	29	7.3

TABLE 10. CONTINUED

no.	Sampled	Fats, oils, and grease lb/day S1	S2	S4	Kjeldahl - N lb/day S1	S2	S4	Nitrate - N lb/day S4	Total-N lb/day S4	Ammonia-N lb/day S1	S4	Temperature °C S3	pH S3
32	7/26/77	No Data											
33	8/2/77	1,386	13.6	11.5	221	121	10.0	4.66	14.7	112	2.4	26	6.6
34	8/9/77	1,418	745.6	17.6	241		13.6	2.63	16.2	127	2.7	27	6.8
35	8/16/77		488.0	27.5	211	150	11.9	5.71	17.6	107	2.1	26	6.6
36	8/23/77	No Data											
37	8/30/77		49.9	25.4	248	123	16.0	51.51	67.5	49	1.1	28	6.8
38	9/6/77		64.7	21.6						72	3.4	25	7.6
39	9/13/77	1,038	62.	17.0	141	91	7.5	15.02	22.5	62	1.0	26	7.4
40	9/20/77	1,408	64.	3.8	261	141	15.9	31.79	47.7	97	2.6	23	6.6
41	9/27/77	1,382	26.	10.7	236	128	14.4	39.29	53.7	81	1.4	25	7.5
42	10/4/77	1,142	133.	6.8	225	142	14.8	33.44	48.2	99	2.8	22	7.3
43	10/11/77	1,153	243.	43.2	195	135	13.5	5.42	18.9	96	6.5	22	6.7
44	10/18/77	1,413	62.6	18.3	209	112	17.5	5.31	22.8	94	6.3		6.6
45	10/25/77	No Data											
46	11/1/77			13.4			8.8	1.60	10.4		2.7		7.1
47	11/8/77			177.0			42.5	0.18	42.7		37.8		7.2
48	11/15/77			19.0			43.4	0.20	43.6		29.8		7.0
49	11/22/77			3.3			10.2	0.38	10.6		5.0	16	7.2
50	11/29/77			15.1			30.0	0.26	30.3		12.7	17	7.3
51	12/6/77			15.5			23.9				19.6	17	7.4
52	12/13/77	1,303	88.0	13.1	216	136	12.6	7.14	19.7	98	6.4	16	7.5
53	12/20/77	1,058	62.4	36.6	202	149	14.9	24.47	39.4	131	5.9	16	7.4
54	12/27/77	850	78.7	0.8	192	121	9.1	0.20	9.3	54	9.1	15	7.1
55	1/3/78	1,212	79.3	22.0	172	117	26.4	0.25	26.7	82	15.4	15	7.2
56	1/10/78	1,788	146.2	4.7	274	170	9.7	0.20	9.9	112	9.7	15	7.4
57	1/17/78	1,483	74.3	10.2	222	133	17.2	10.52	27.7	74	14.1	15	7.1
58	1/24/78	862	185.9	13.7	240	156	42.3	5.84	48.1	65	41.8	16	7.1
59	1/31/78	1,624	201.6	6.0	222	144	36.7	0.08	36.8	115	41.9	15	7.0
60	2/7/78	1,501	190.6	8.9	188	136	43.9	0.26	44.2	71	42.3	16	7.3

Discussion of graphs of analytical results.

The results as depicted in the graphs indicate operational features and dependent variables that have occurred during the three periods. Comments upon each graph follow:

Figure 14. BOD vs. Week: This graph indicates that biological stability or consistency was not established until about the 20th week of operation. The overall results indicate a BOD of 10 to 20 lb/day (4 to 8 mg/l) is readily achieved. The special test periods do not indicate any abnormalities.

Figure 15. pH and Temperature vs. Week: A notable indication in this graph is that the plant was put into operation during a very cold period which was generally much colder than the winter of 1977-78. This curve might seemingly indicate that the reason for the long break-in period was the cold weather, but other factors such as operational problems in the primary and secondary and overall plant break-in problems were equally significant.

Figure 16. F/M vs. Week: This curve shows that the design F/M of 0.06 was not reached until about the 20th week of operation. The best BOD efficiency is seen to occur during the lowest F/M loading periods.

Figure 17. Sludge Age vs. Week: This curve indicates that the sludge age is over 30 days which insures the sludge to be aerobically digested.

Figure 18. MLSS, MLVSS, and SVI vs. Week: This curve indicates a very good set of values for SVI, but it also shows that the MLSS is much higher than designed or expected.

Figure 19. Suspended Solids vs. Week: This graph indicates a higher than expected amount of suspended solids in the effluent. The very high MLSS or solids in the aeration unit can be imagined to be the cause, but other reasons including final clarifier upset, erratic sludge return, and inability to waste excess sludge were responsible in part.

Figure 20. Nitrogen vs. Week: The nitrogen plots indicate a trend toward consistent nitrogen removal which seems to be independent of temperature or pH. The erratic values indicate a need for refinement in operational procedures, but no change in the design.

Figure 21. Ammonia vs. Week: This curve indicates a potential for high ammonia removal. It also seems to indicate that nitrification and denitrification maximizes during the summer or warm water temperature period.

Figure 22. Fats, Oils and Grease vs. Week: This plotting indicates erratic primary and secondary removal, but a very consistent overall removal.

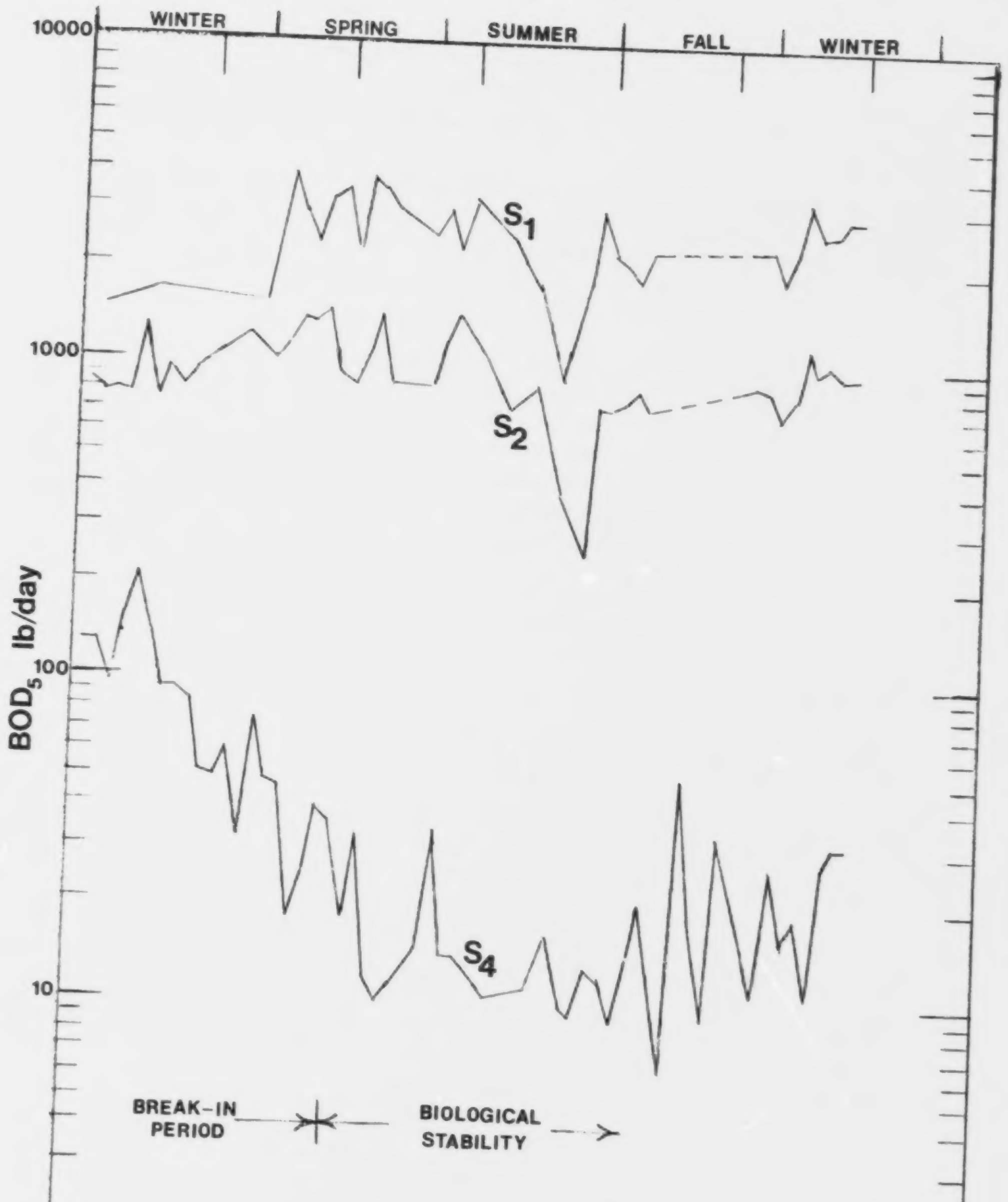

Figure 14. BOD$_5$ levels in raw wastewater, after primary treatment, and after total treatment. First sixty weeks.

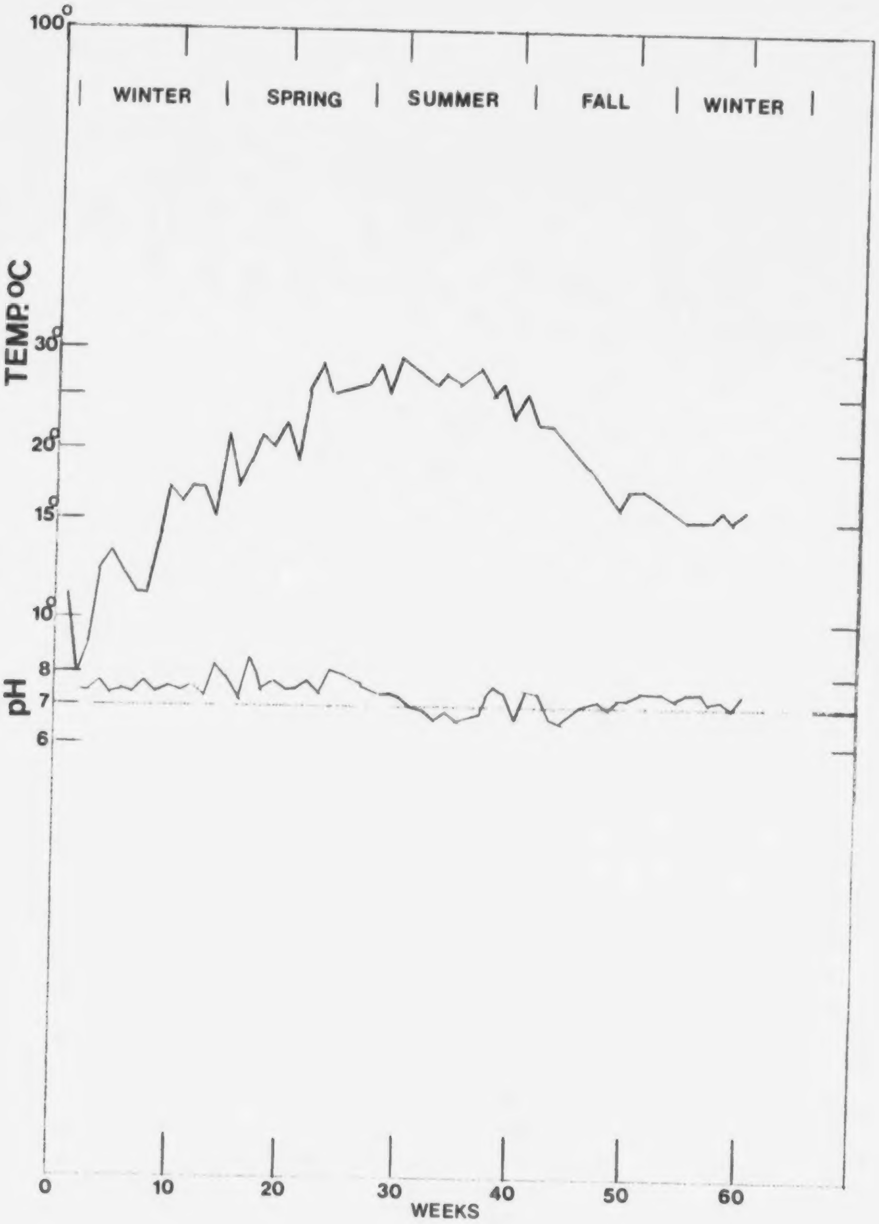

Figure 15. Temperature and pH in the carrousel. First sixty weeks.

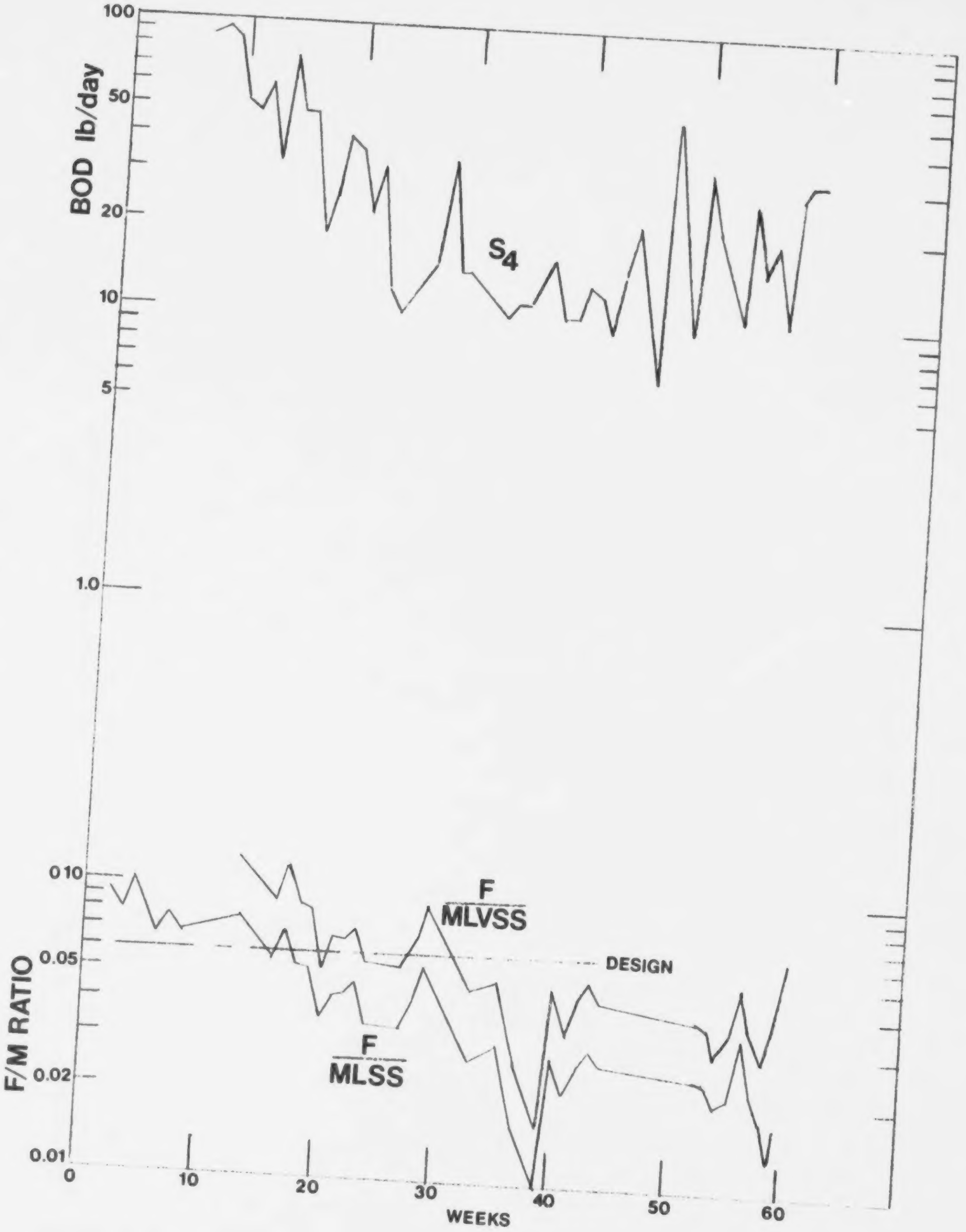

Figure 16. Food to microorganisms ratio and relationship to final BOD_5. First sixty weeks.

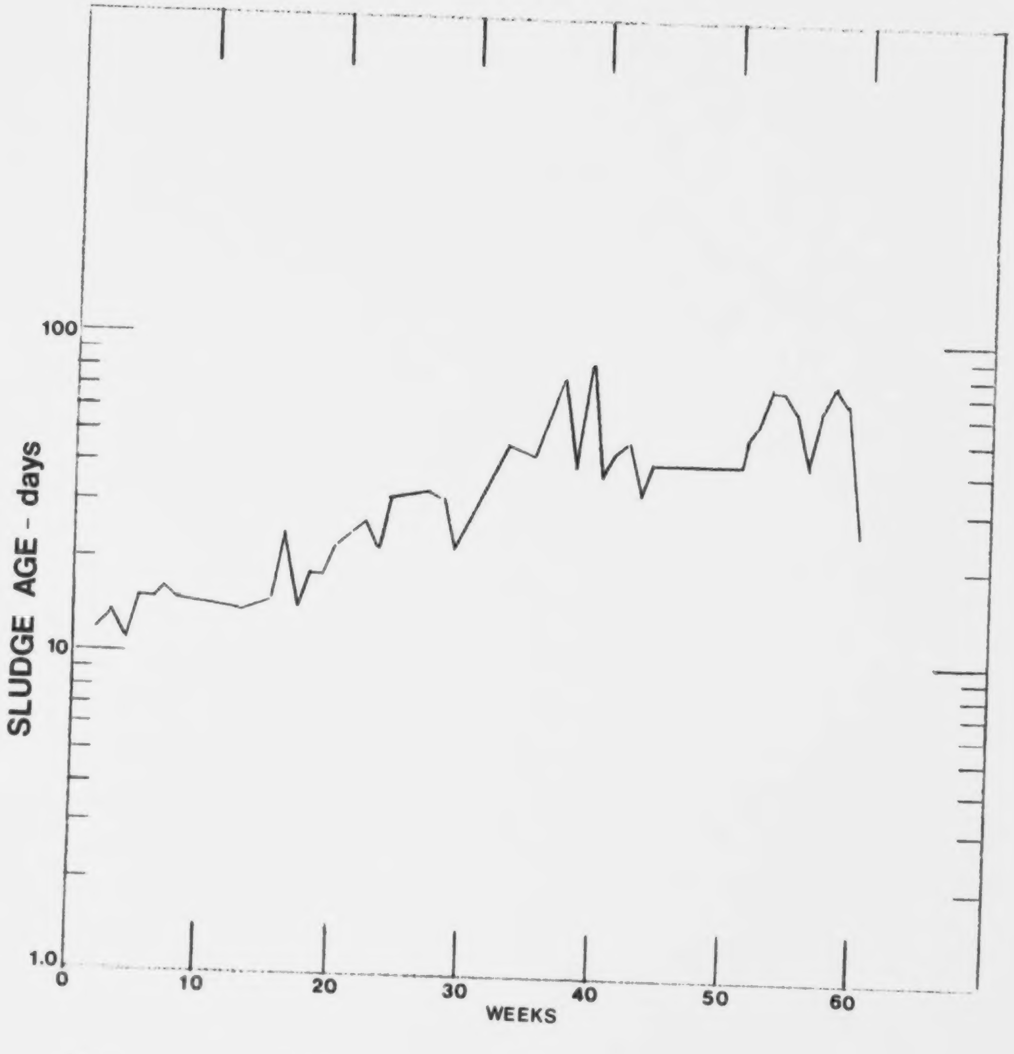

Figure 17. Average age of suspended solids in the carrousel. First sixty weeks.

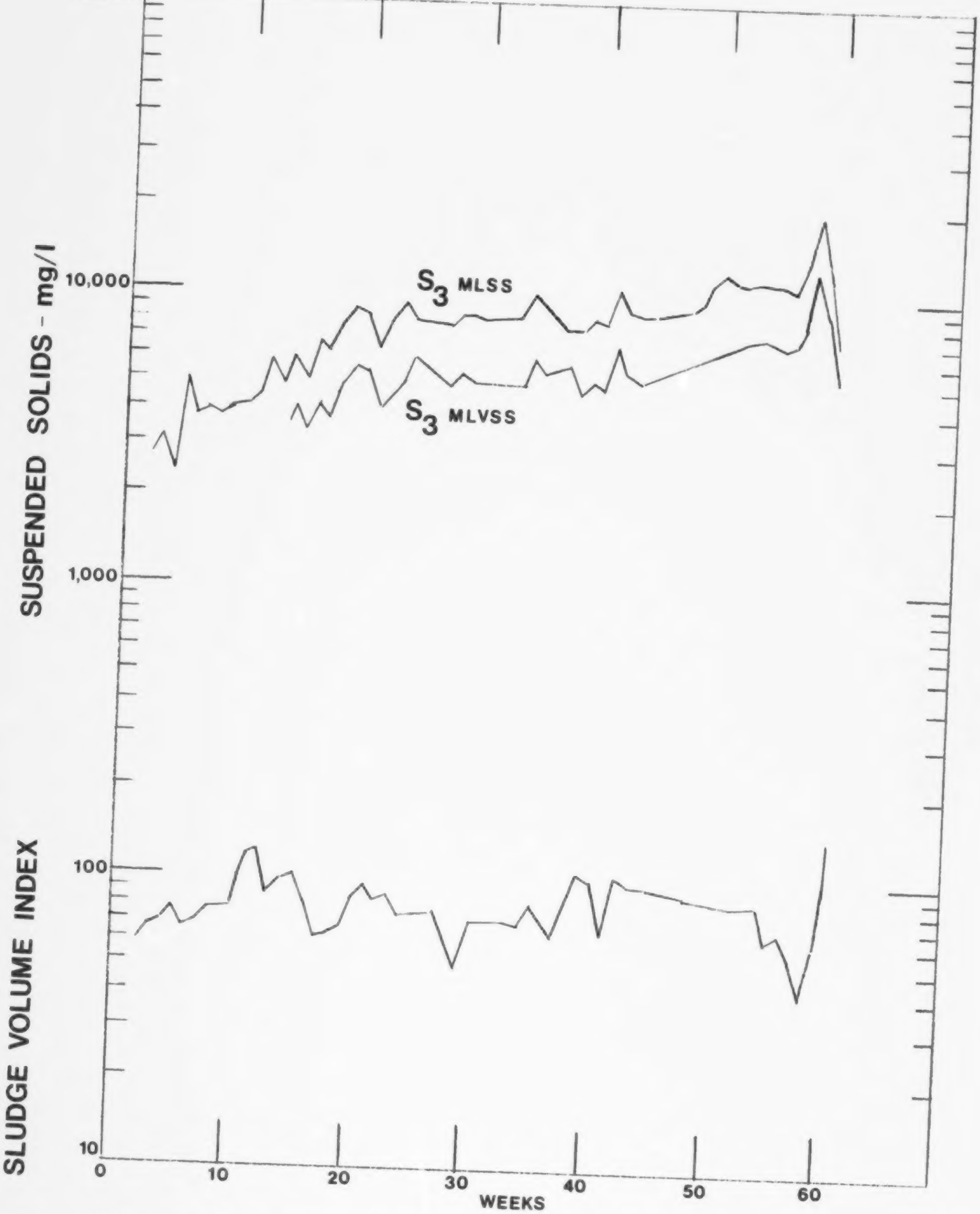

Figure 18. Suspended solids in the carrousel and sludge volume index. First sixty weeks.

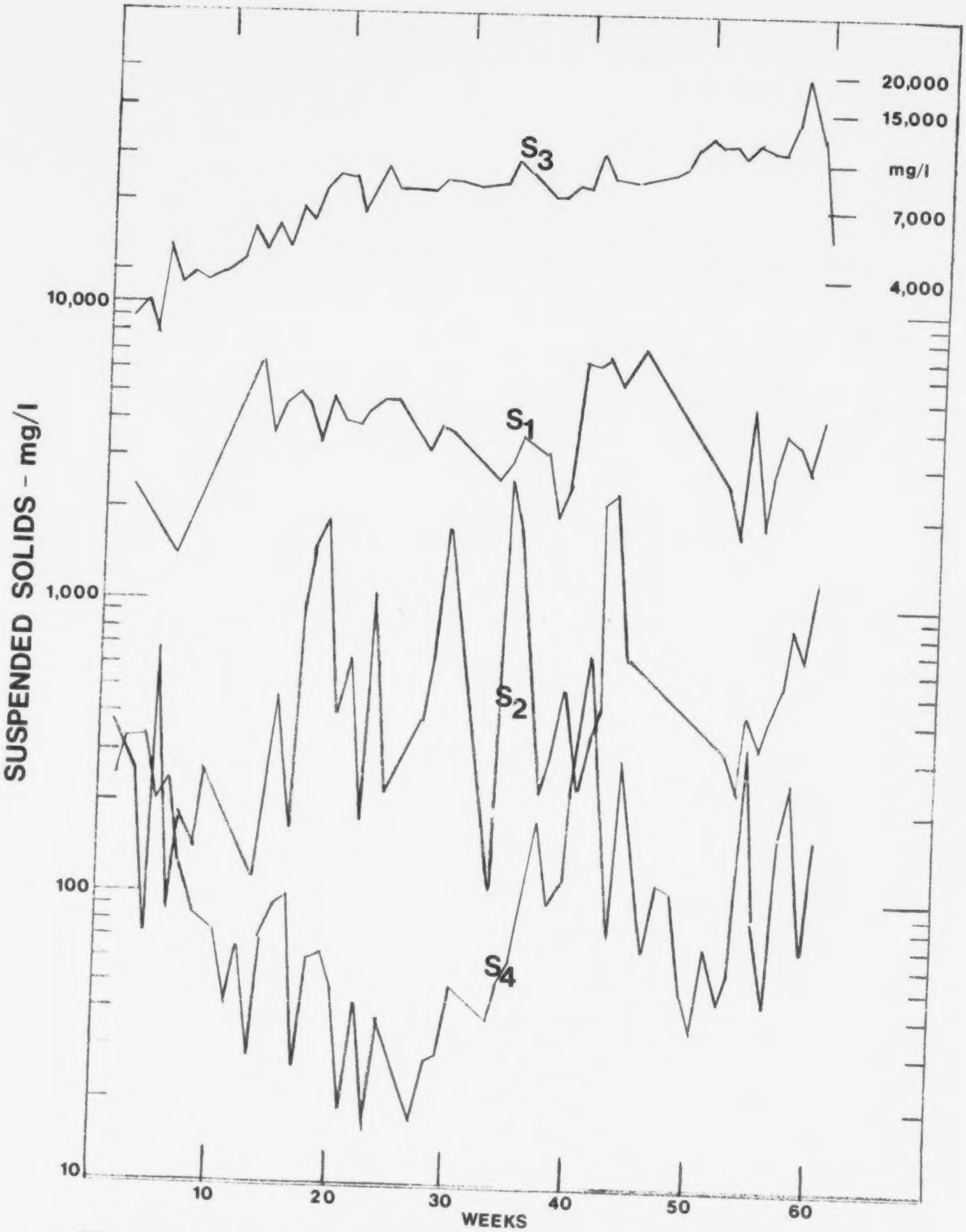

Figure 19. Suspended solids in raw wastewater; after primary treatment; and after total treatment. First sixty weeks.

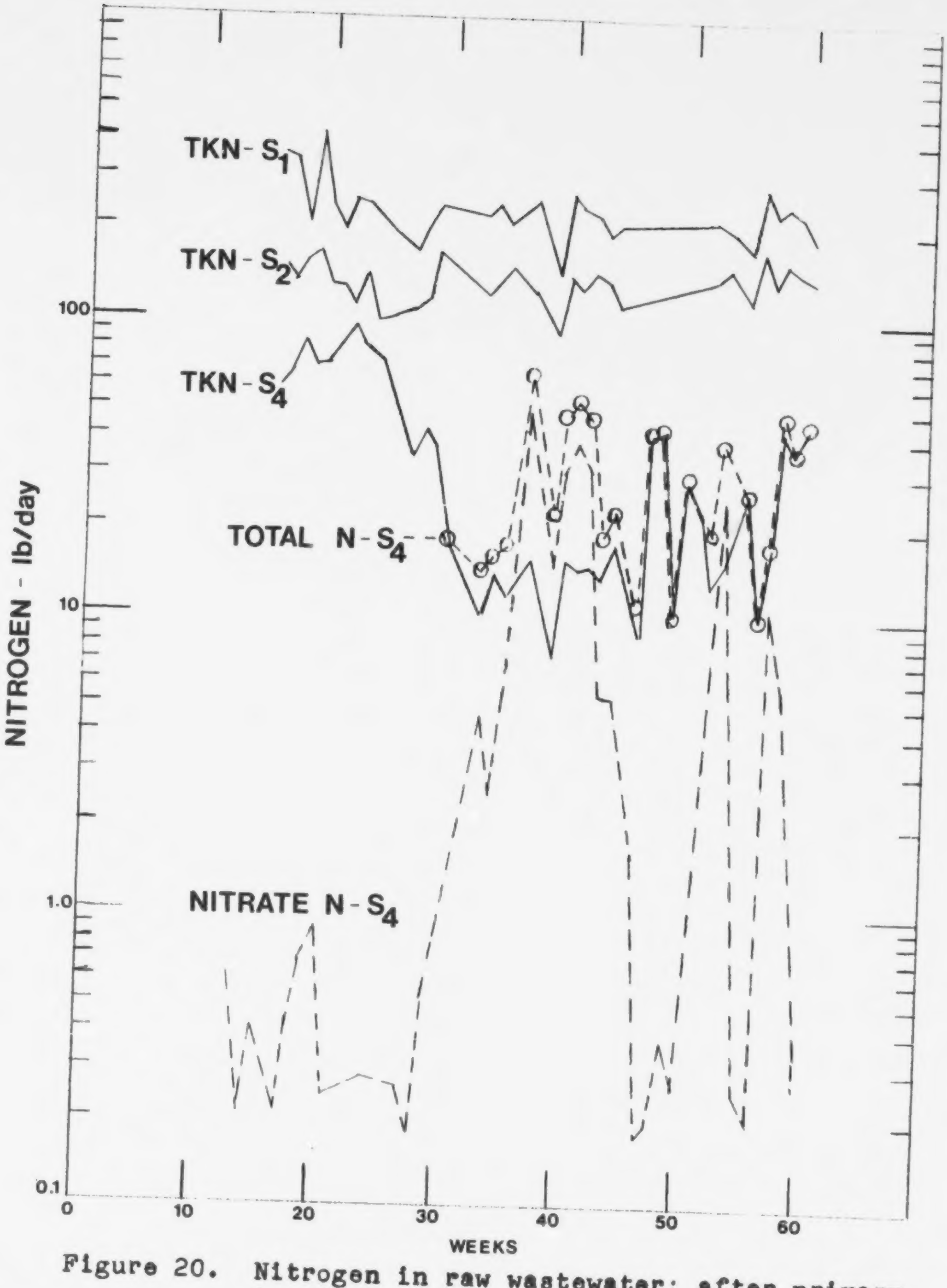

Figure 20. Nitrogen in raw wastewater; after primary treatment; and after total treatment. First sixty weeks.

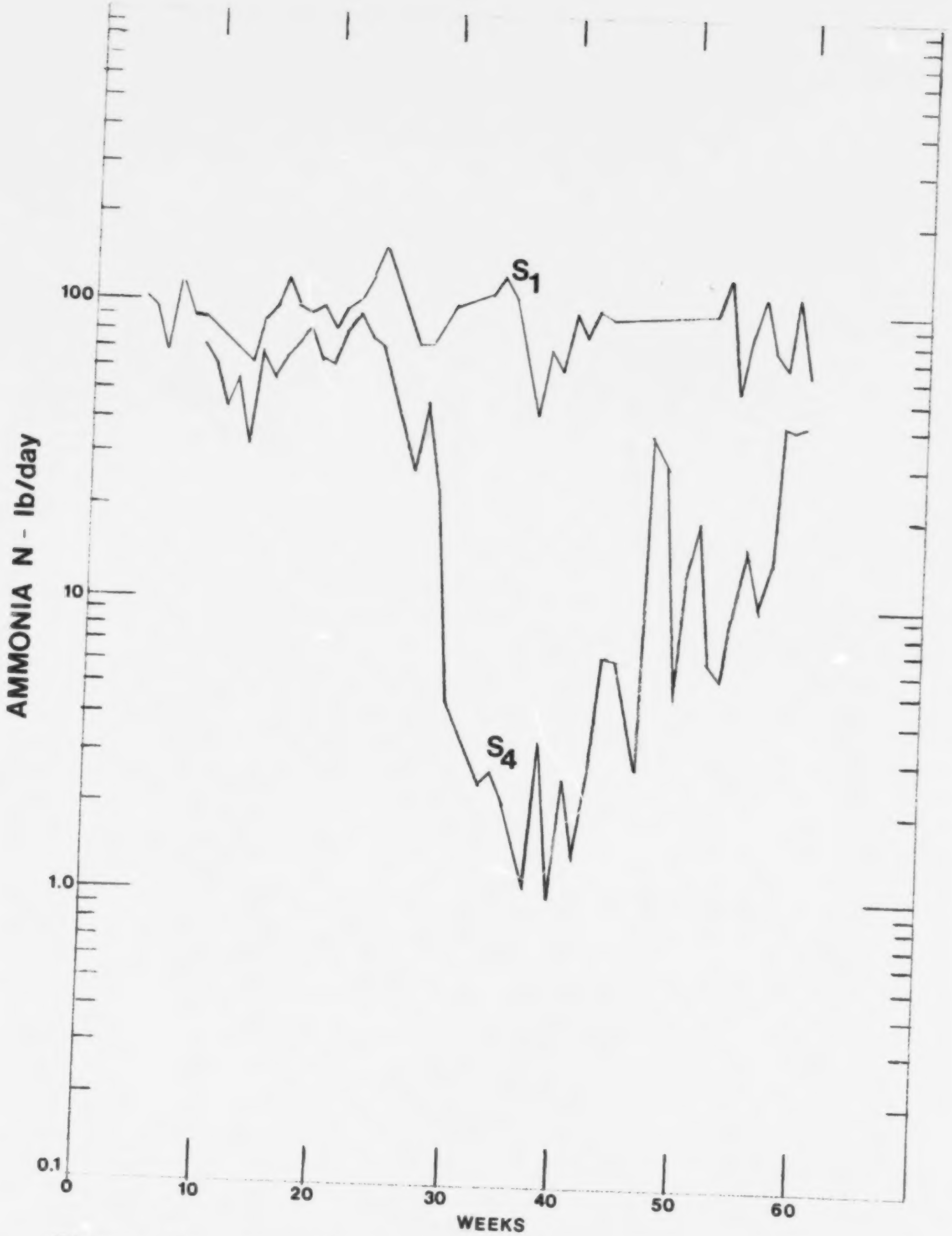

Figure 21. Ammonia nitrogen in raw wastewater; and after total treatment. First sixty weeks.

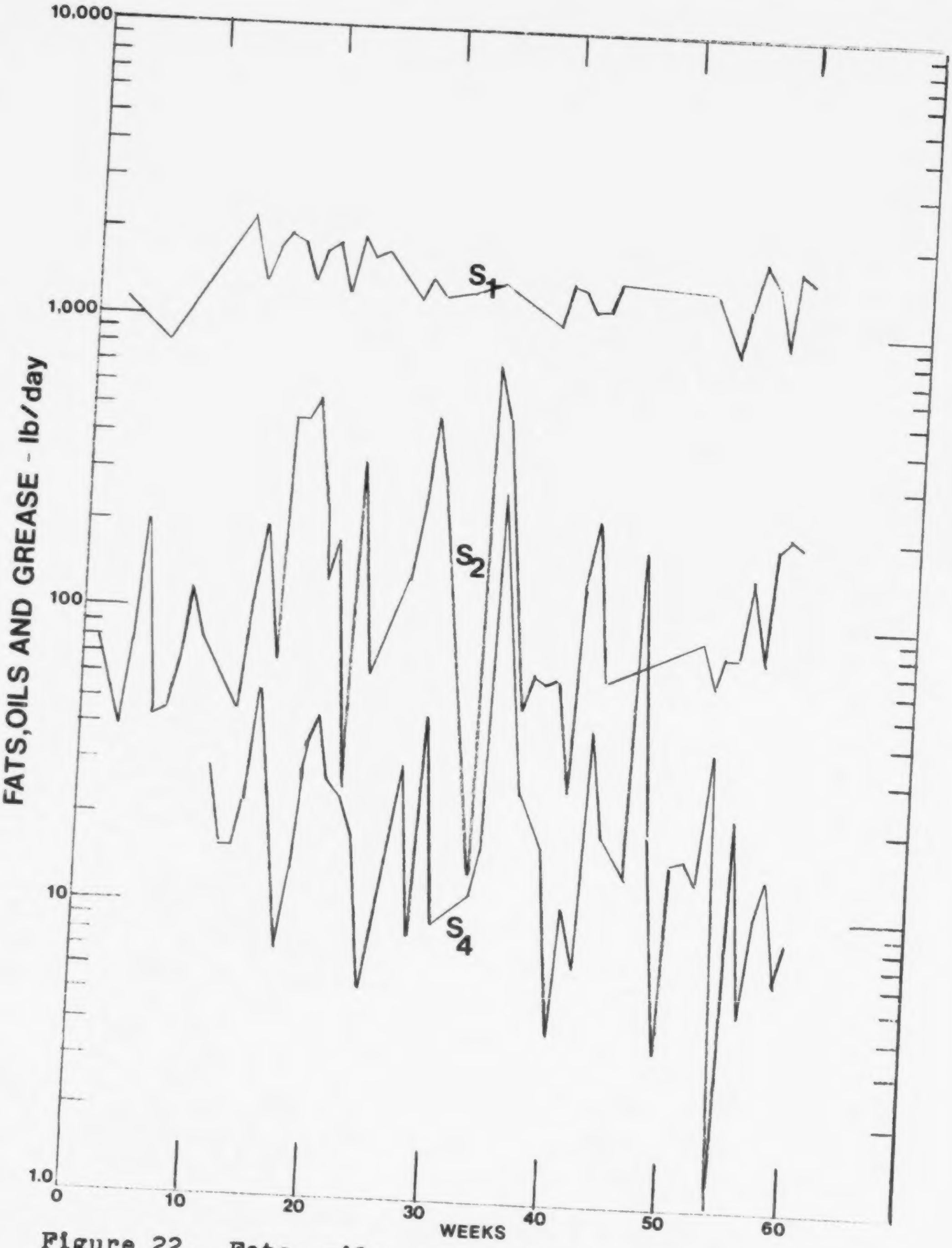

Figure 22. Fats, oils, and grease in raw waste-water; after primary treatment; and after total treatment. First sixty weeks.

Figure 23. Chromium vs. Week: The characteristics of this plot are similar to the previous Fats, Oils and Grease curves. Content in the final effluent is low and consistent.

Figure 24, 25 BOD vs % Frequency: This set of plots indicates good removal and or satisfaction of BOD as shown by the effluent BOD at S_4. The results would be better if the solids were filtered from the samples prior to analyzing for BOD. The efficiency is seen to be the same for the two special test periods. The variations are about what they would be expected to be.

Figure 26, 27 Suspended Solids vs. % Frequency: The primary significance in this set of plots is the relatively poor removal of solids in the secondary clarifier. The MLSS in the aeration unit is much higher than the design. This was due to a combination of reasons which will ultimately be corrected, including inability to waste excess sludge on a set schedule because of clogging of return pumps. This difficulty also contributed to the high solids content in the final effluent. The secondary clarifier was subject to settling upsets and short circuiting assumed to be due to changes which the unit could not handle. The overall plant efficiency is over 90% and does not vary greatly with seasonal changes.

Figure 28, 29 SVI vs. % Frequency: The consistent value of less than 100 indicates a very stable sludge condition. The sludge condition changed somewhat from the first test period to the second but the amount of MLSS also changed appreciably.

Figure 30, 31 Suspended Solids (% Volatile) vs. % Frequency: This set of plots did not indicate anything significant except to show the great variation in the primary effluent and the consistently low MLVSS content in the aeration unit. The low volatile percentage can be assumed to be due to carryover of suspended solids from the primary section.

Figure 32, 33 Nitrogen vs. % Frequency: These plots indicate one of the most important determinations of this demonstration project, the ability of the secondary treatment to remove over 70% of the total nitrogen summer or winter. During the summer more nitrate and less ammonia occured in the effluent than during the winter test period, but the overall nitrogen removal for the total plant was greater in the winter 90% to 84%. The erratic results were due to operational trials, changes, and adjustments, but the overall ability to remove substantial amounts of nitrogen can be seen. More work must be done on optimizing the operation through instrumentation in order to eliminate operator control and error.

Figure 34, 35 TKN vs. % Frequency: This set of plots is very similar to the total nitrogen plots, Figures 15 & 24. When nitrates are present the total nitrogen includes them, as in Figure 20, but they are not included in the TKN. The TKN includes NH_3. It does not, by itself, indicate the degree of nitrification.

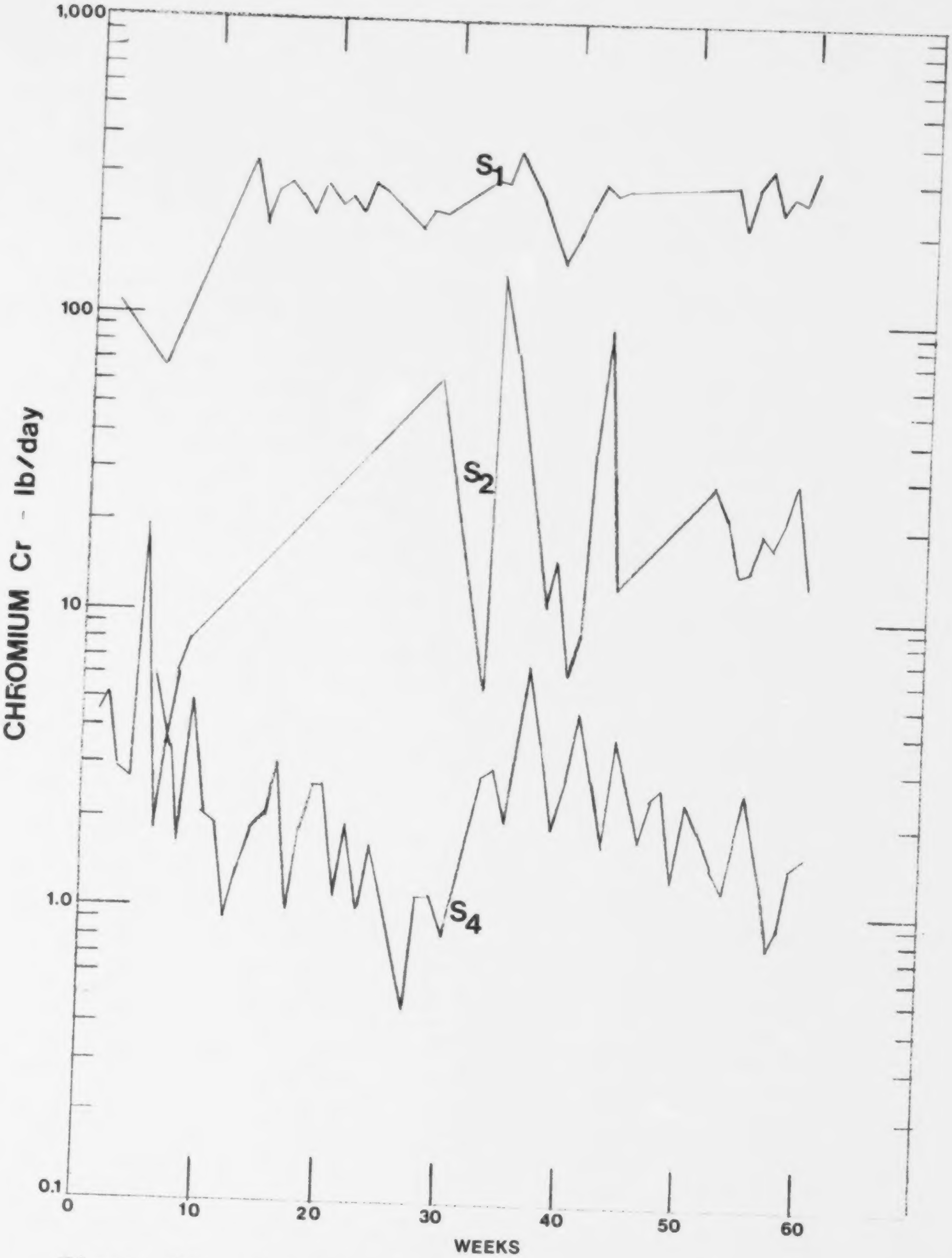

Figure 23. Chromium in raw wastewater; after primary treatment; and after total treatment. First sixty weeks.

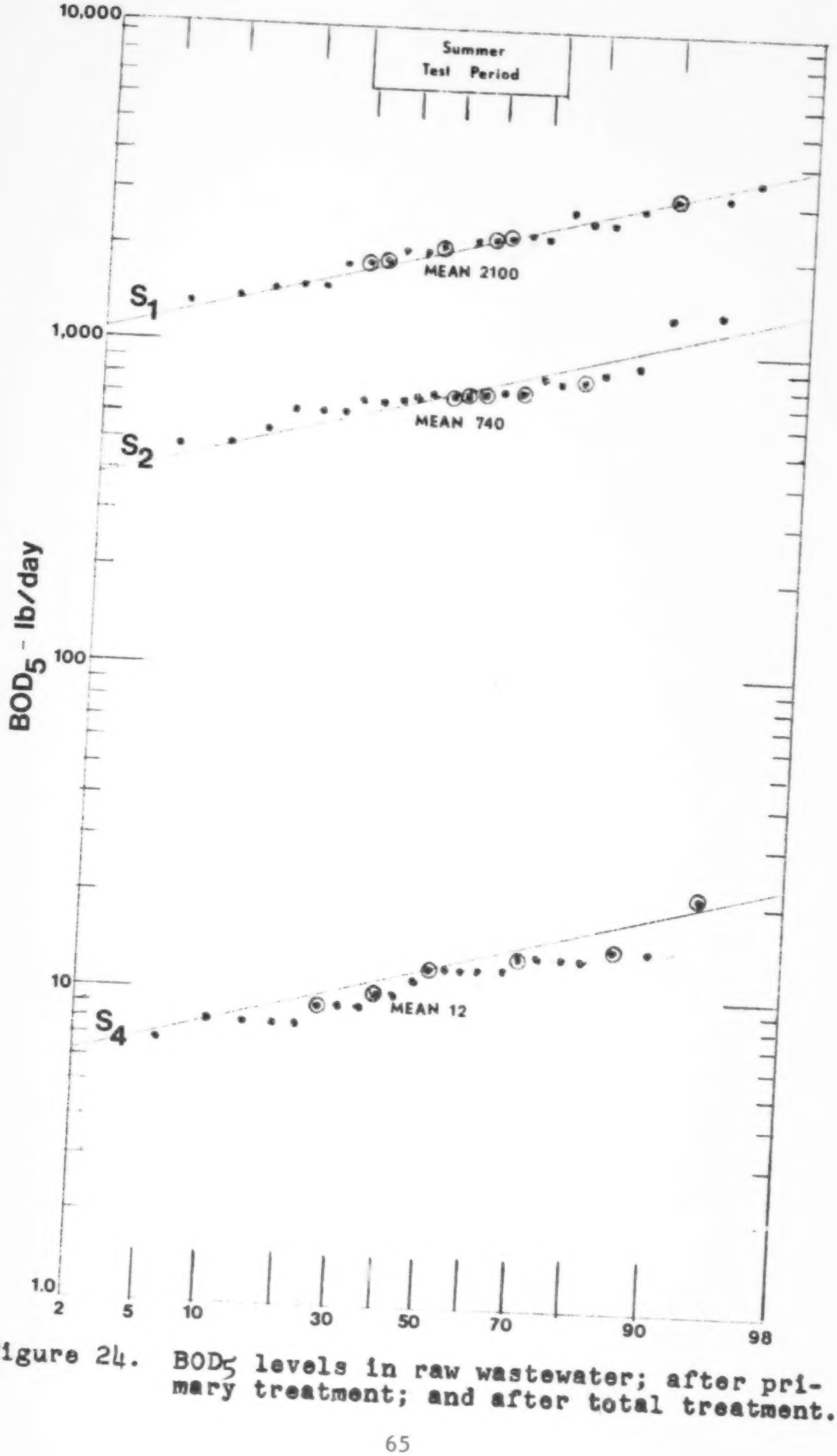

Figure 24. BOD_5 levels in raw wastewater; after primary treatment; and after total treatment.

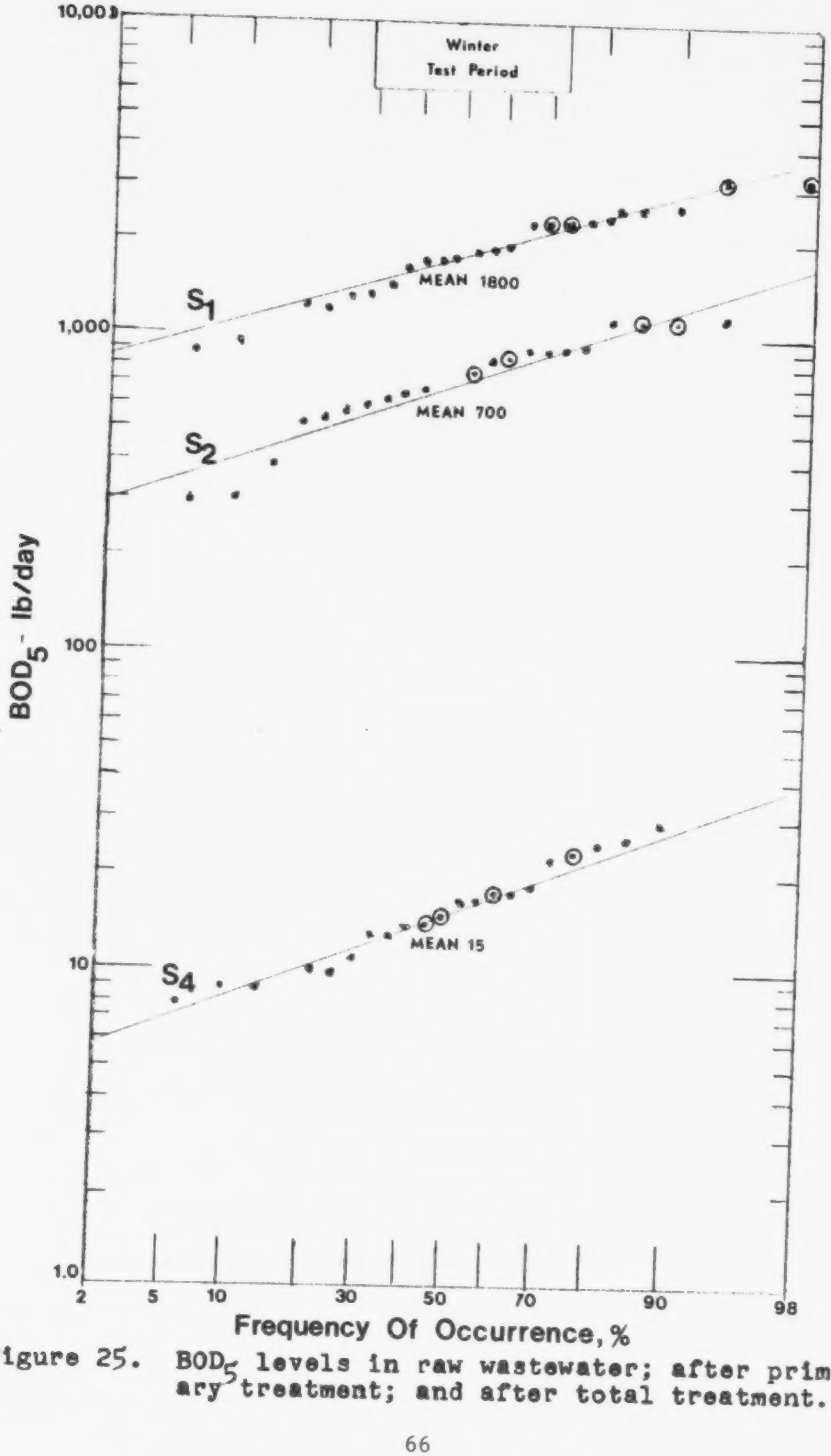

Figure 25. BOD_5 levels in raw wastewater; after primary treatment; and after total treatment.

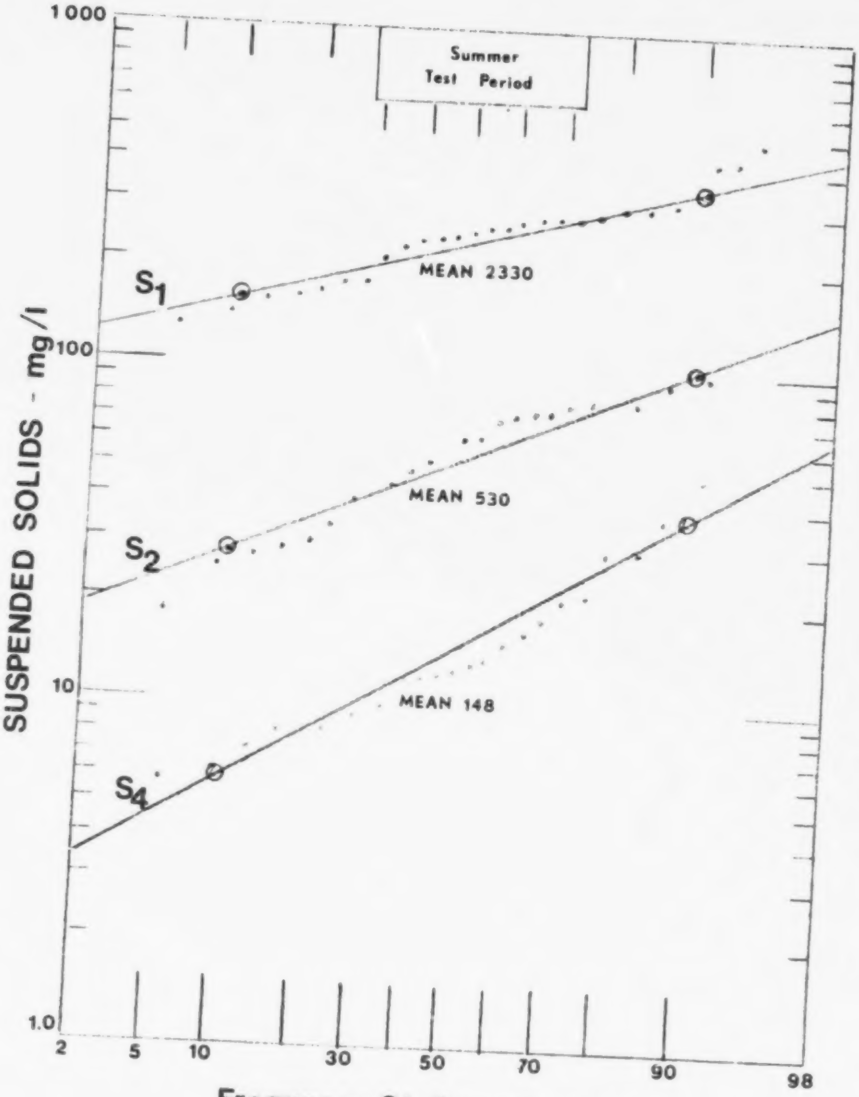

Figure 26. Suspended solids levels in raw wastewater; after primary treatment; and after total treatment

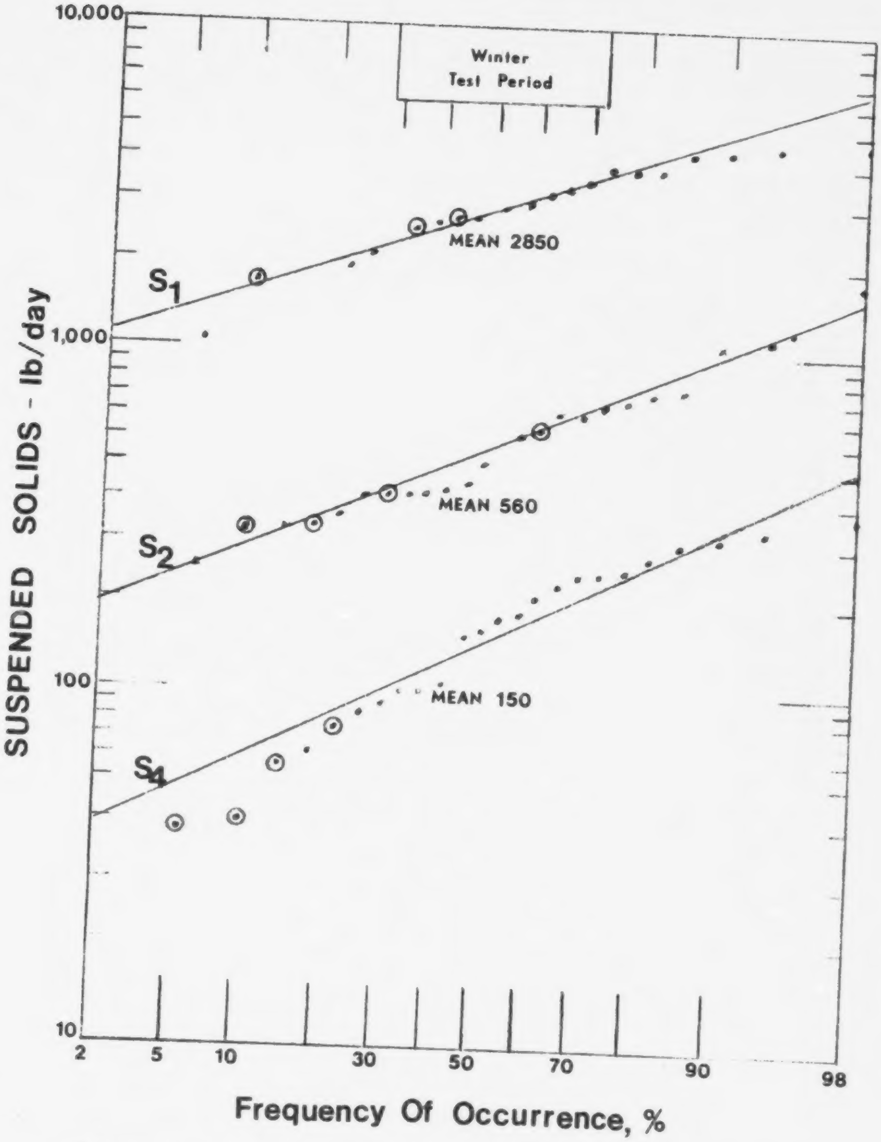

Figure 27. Suspended solids levels in raw wastewater; after primary treatment; and after total treatment.

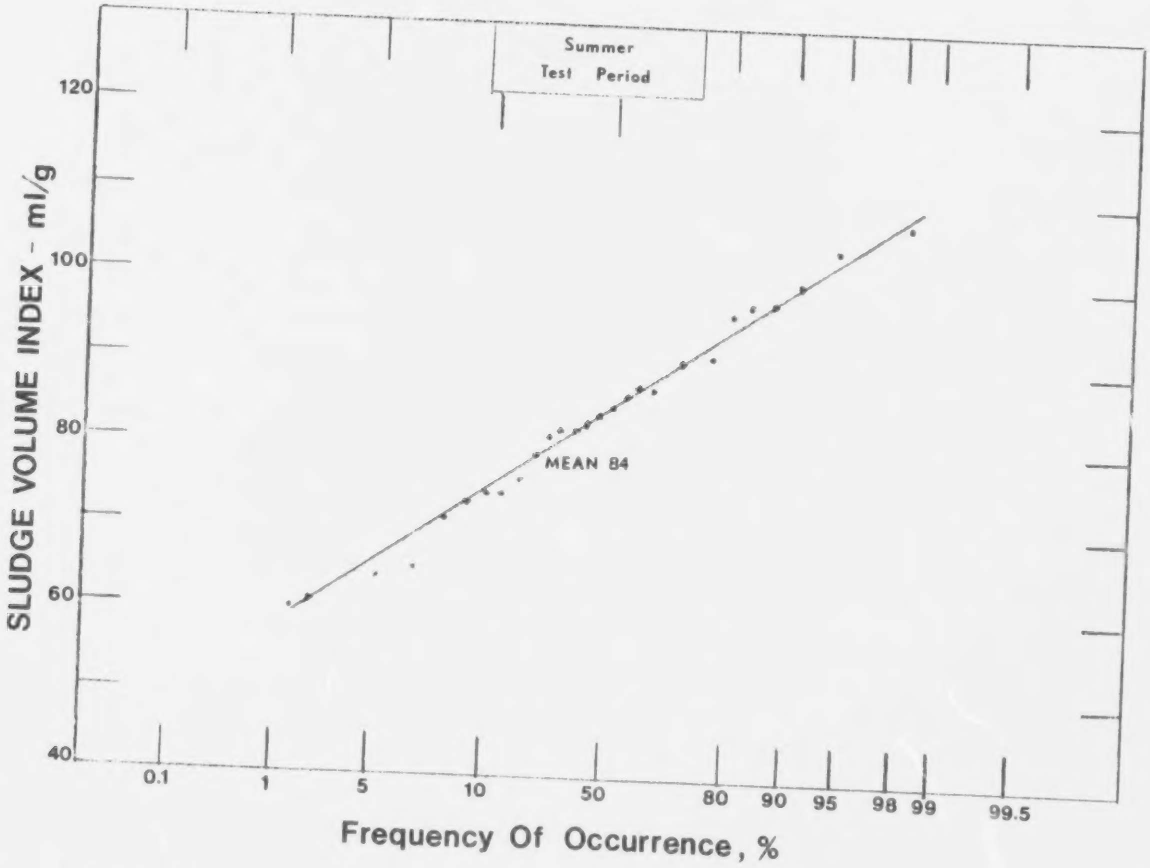

Figure 28. Sludge volume index for carrousel activated sludge

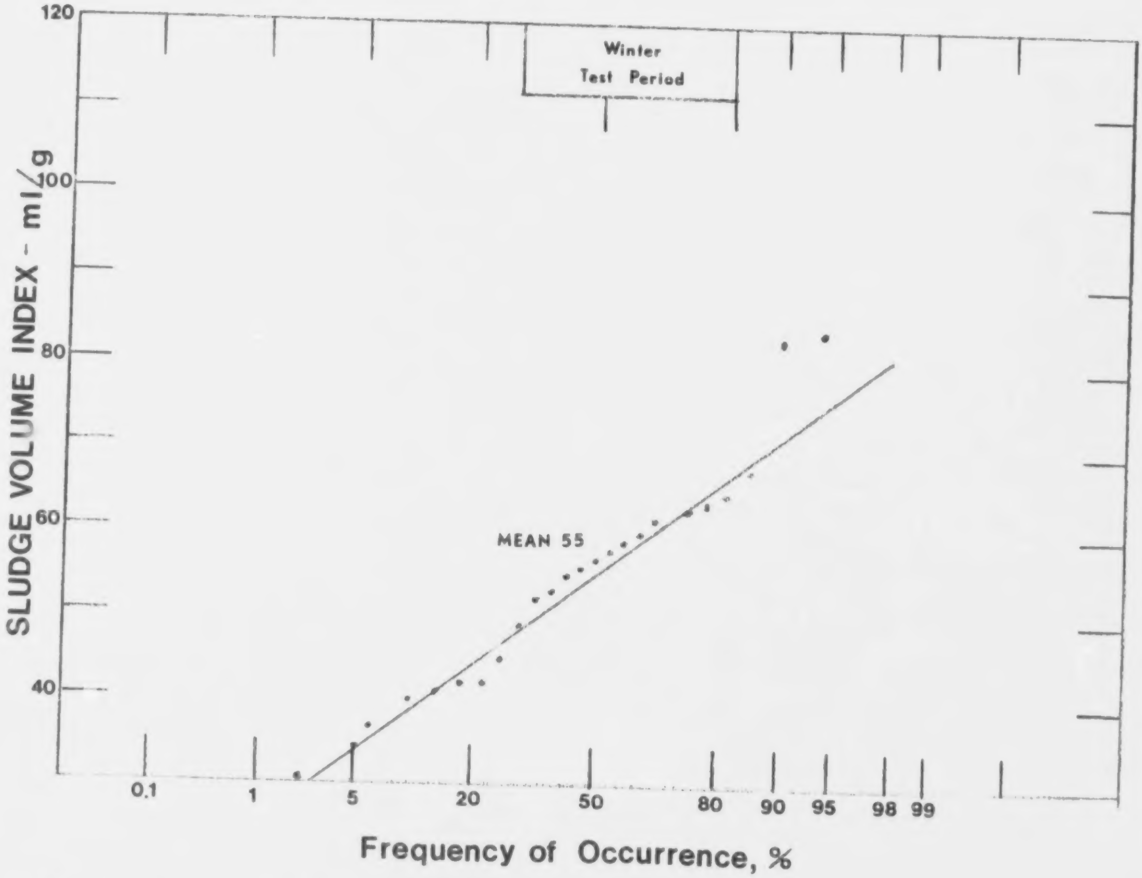

Figure 29. Sludge volume index for carrousel activated sludge.

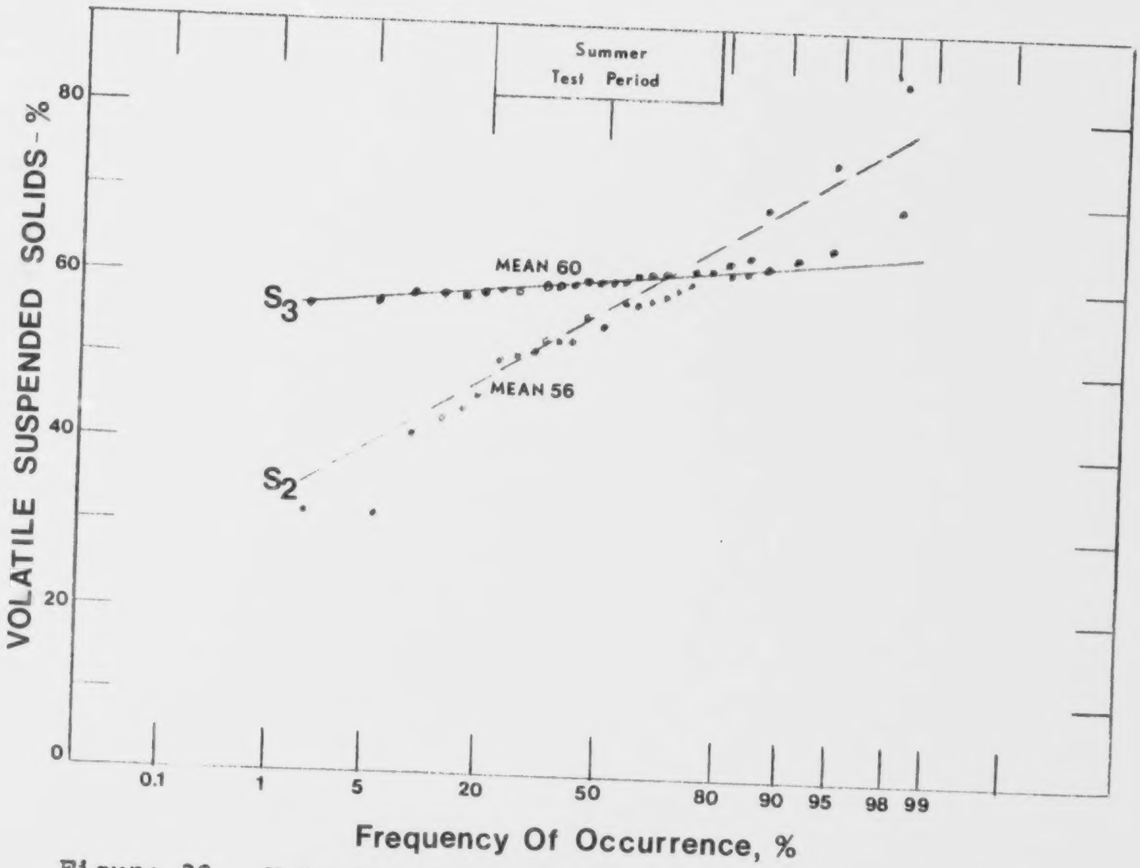

Figure 30. Volatile suspended solids levels after primary treatment, and in the carrousel.

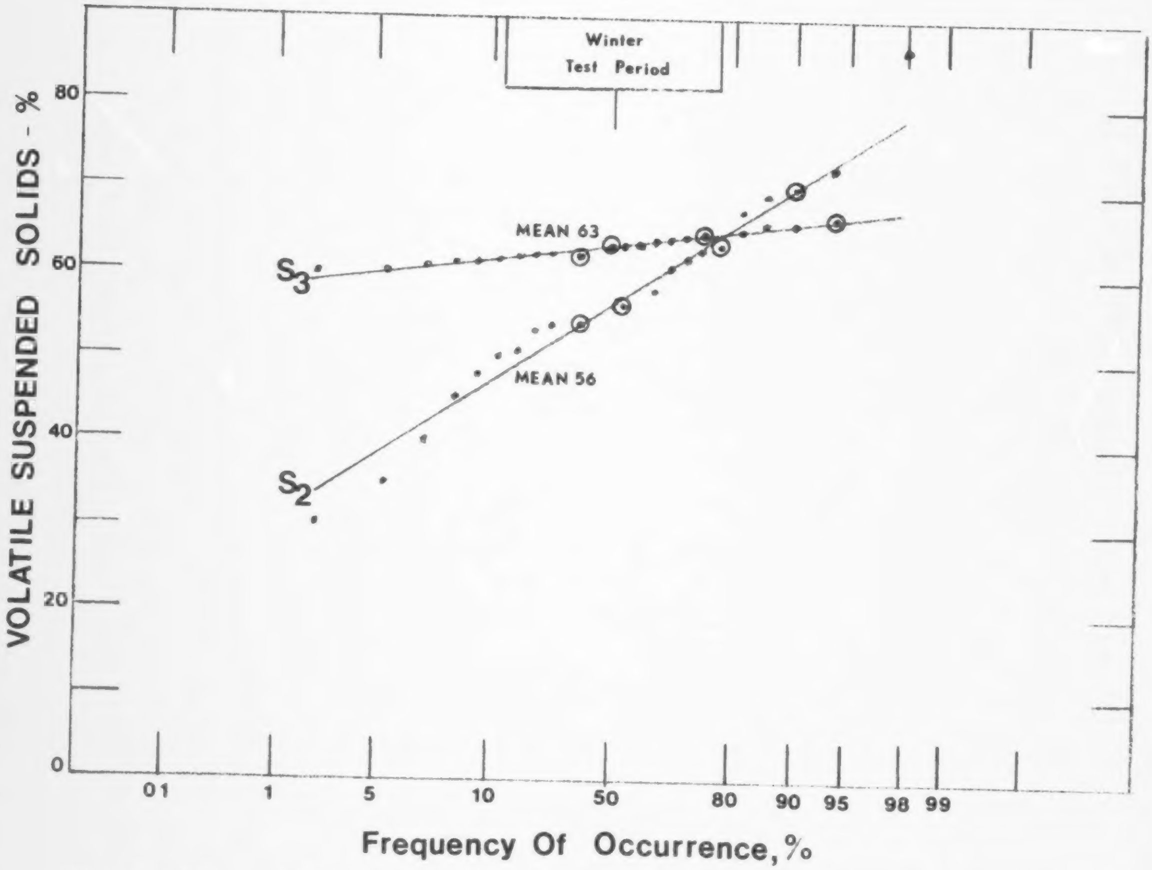

Figure 31. Volatile suspended solids levels after primary treatment, and in the carrousel.

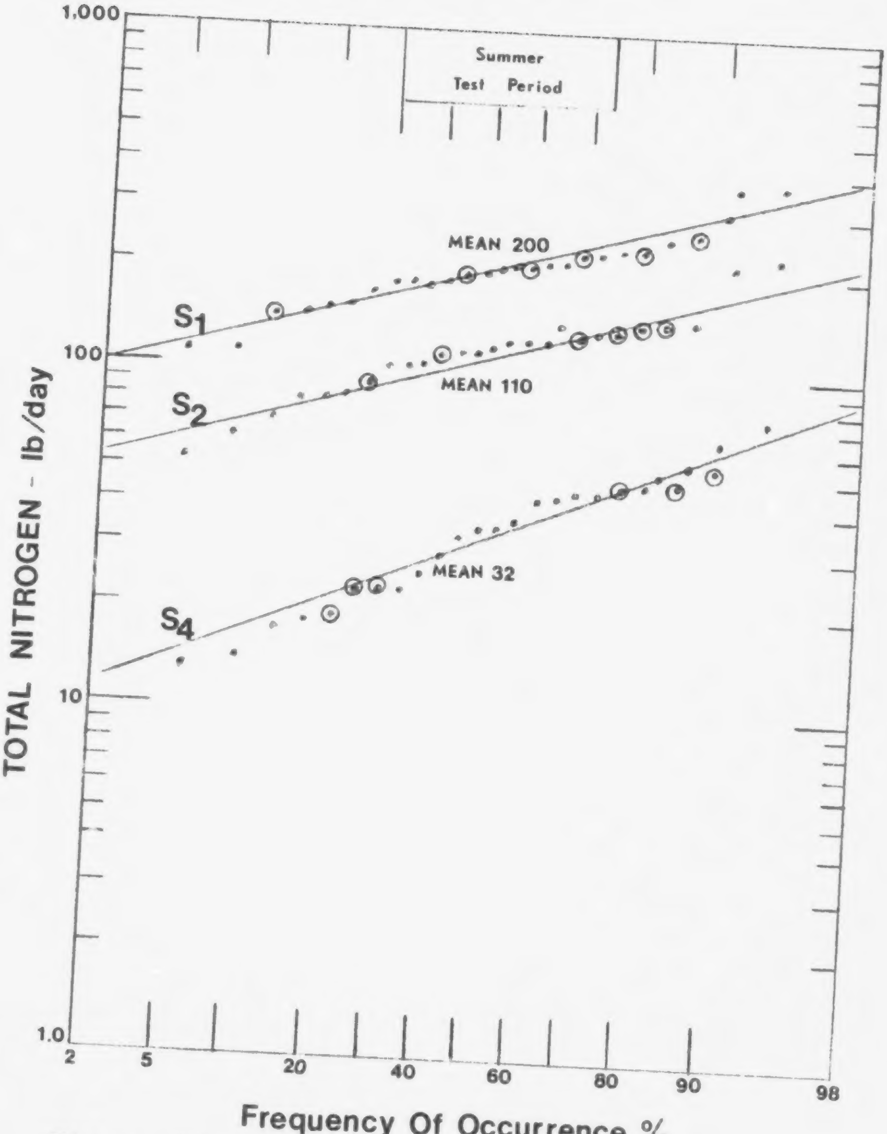

Figure 32. Total nitrogen levels in raw wastewater; after primary treatment; and after total treatment.

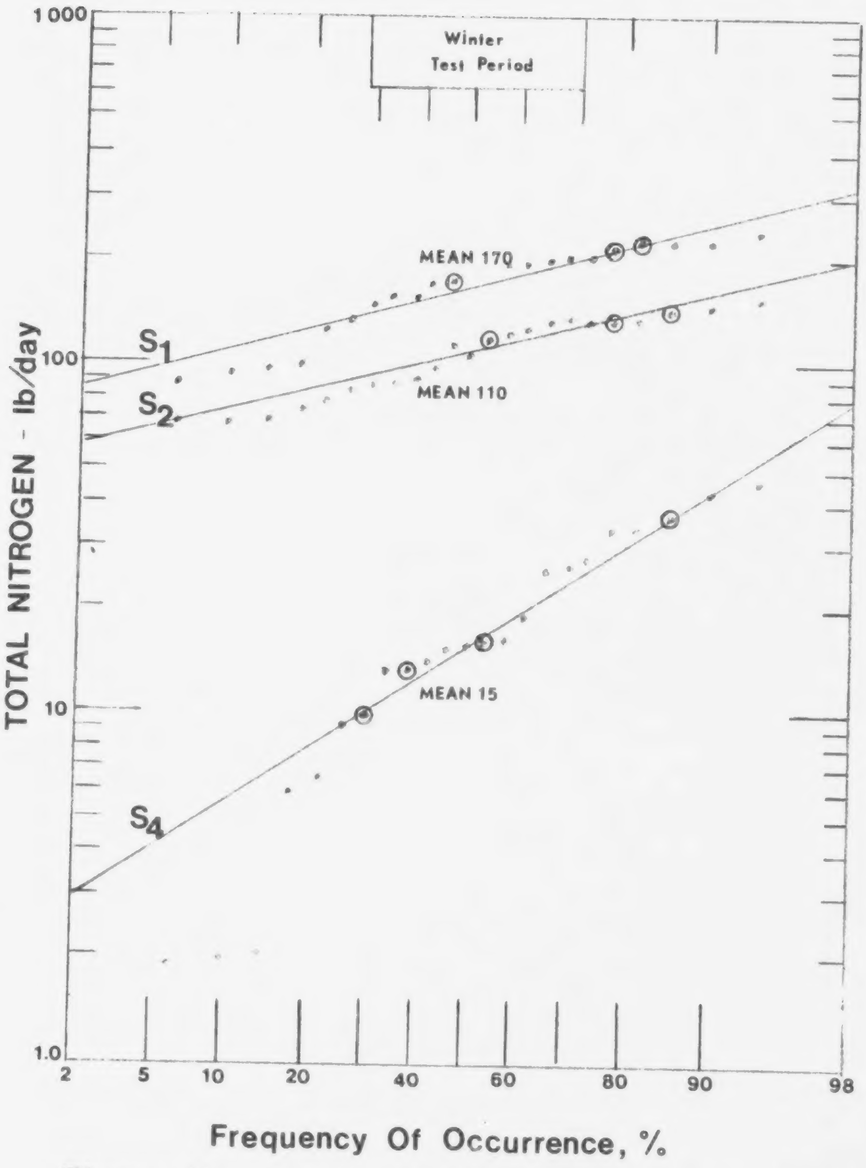

Figure 33. Total nitrogen levels in raw wastewater; after primary treatment; and after total treatment.

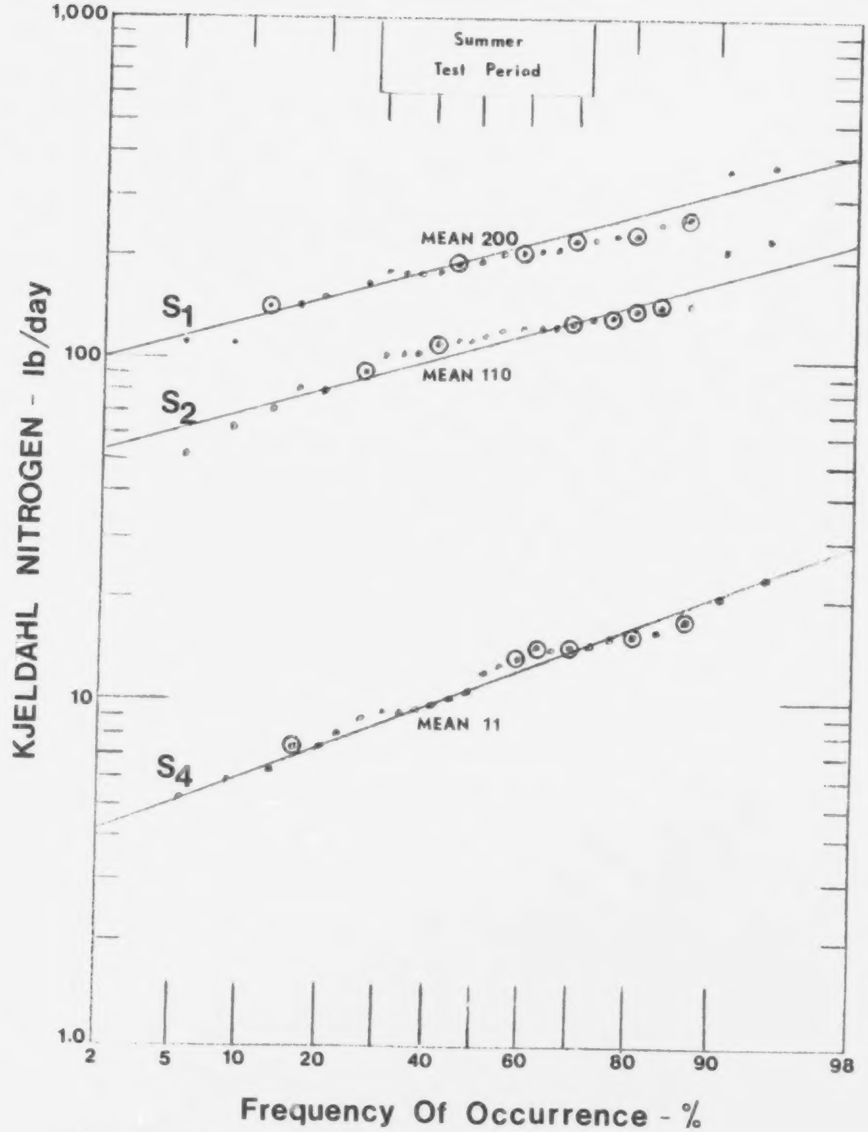

Figure 34. Kjeldahl nitrogen levels in raw wastewater; after primary treatment; and after total treatment.

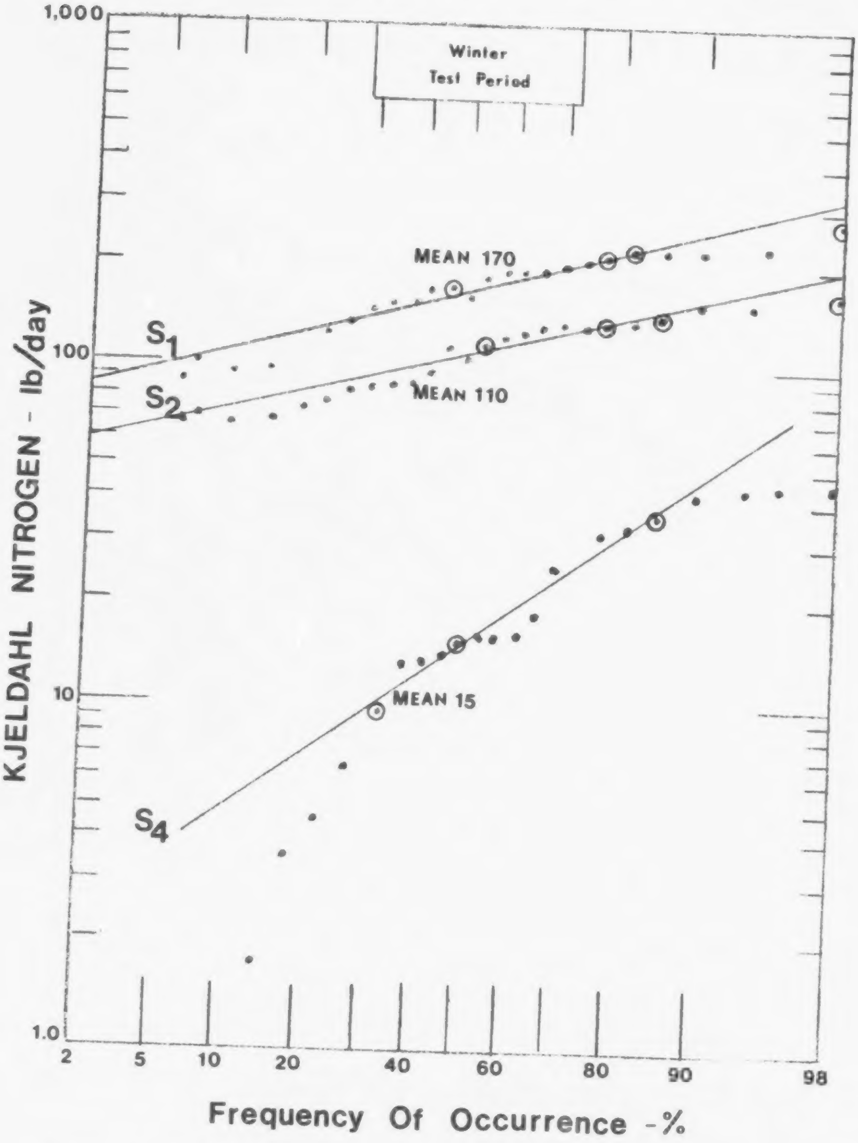

Figure 35. Kjeldahl nitrogen levels in raw wastewater; after primary treatment; and after total treatment.

Figure 36, 37	Ammonia vs. % Frequency: This graph indicates very good removal or conversion of NH_3. It also indicates better efficiency during the summer test period.
Figure 38, 39	Fats, Oils and Grease (FOG) vs. % Frequency: This plot shows consistency, good removal, and low effluent concentration.
Figure 40, 41	Chromium vs. % Frequency: The most important observation in this set of plots is the consistently high removal efficiency and the low final effluent concentration.

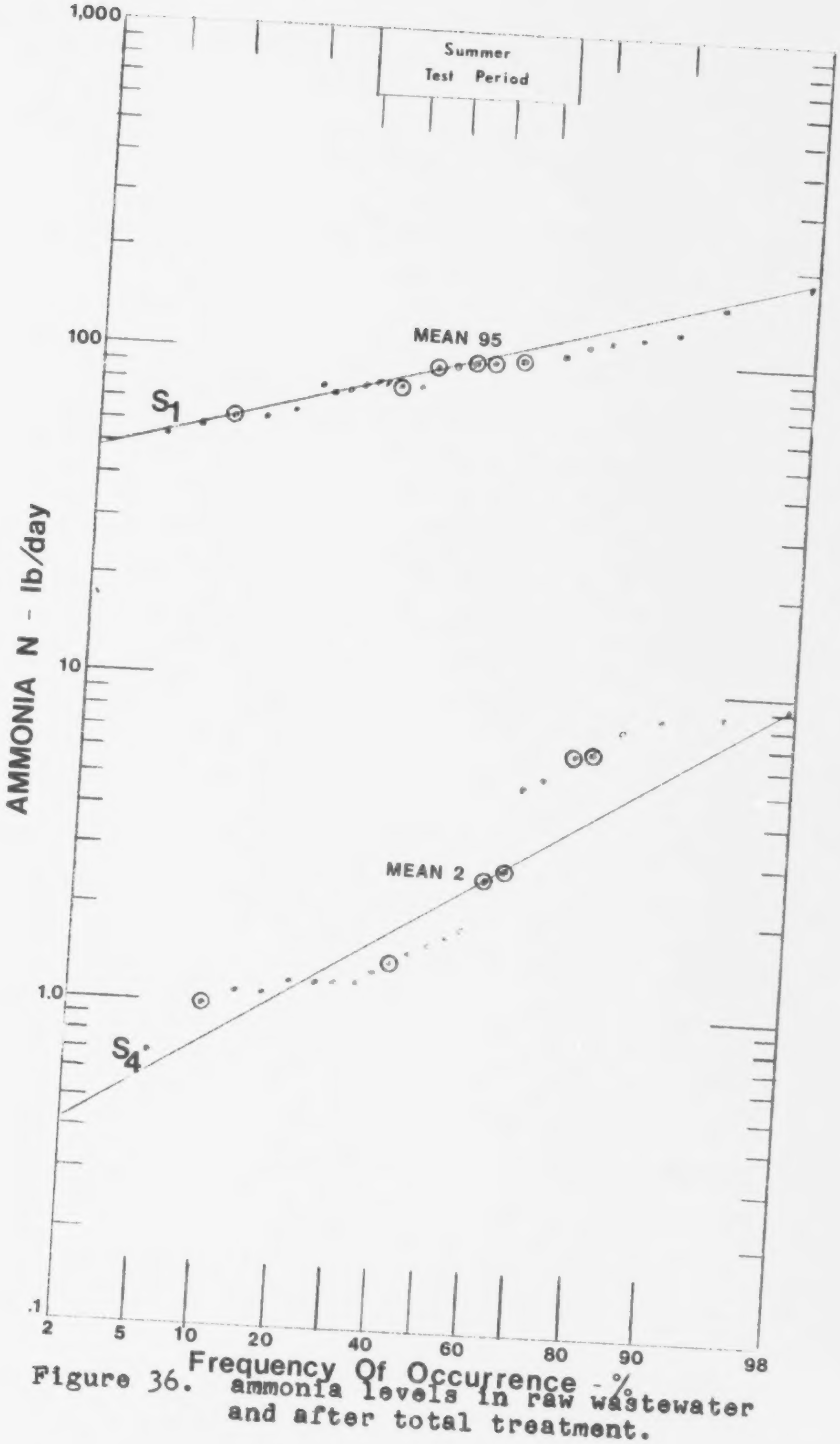

Figure 36. ammonia levels in raw wastewater and after total treatment.

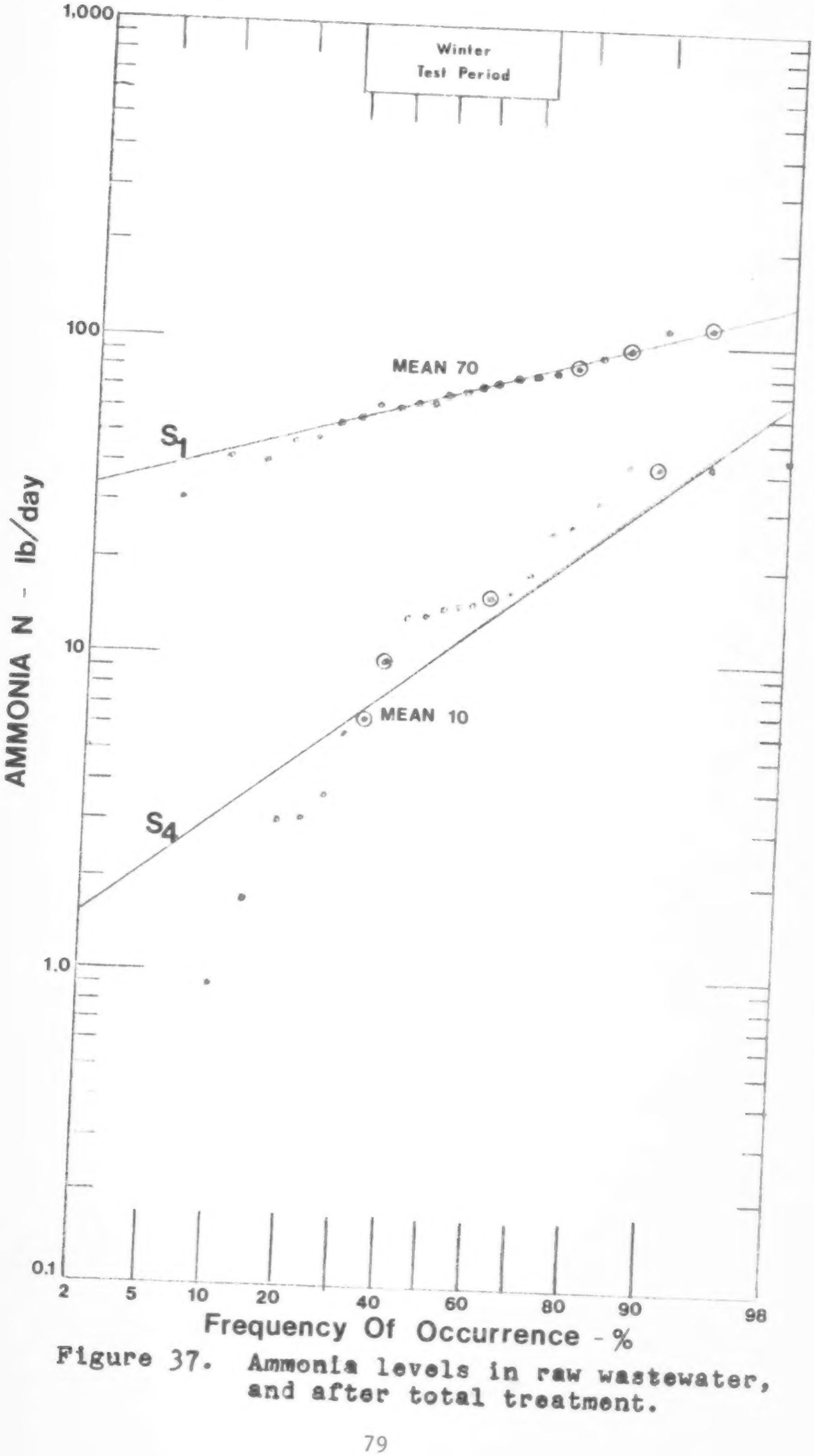

Figure 37. Ammonia levels in raw wastewater, and after total treatment.

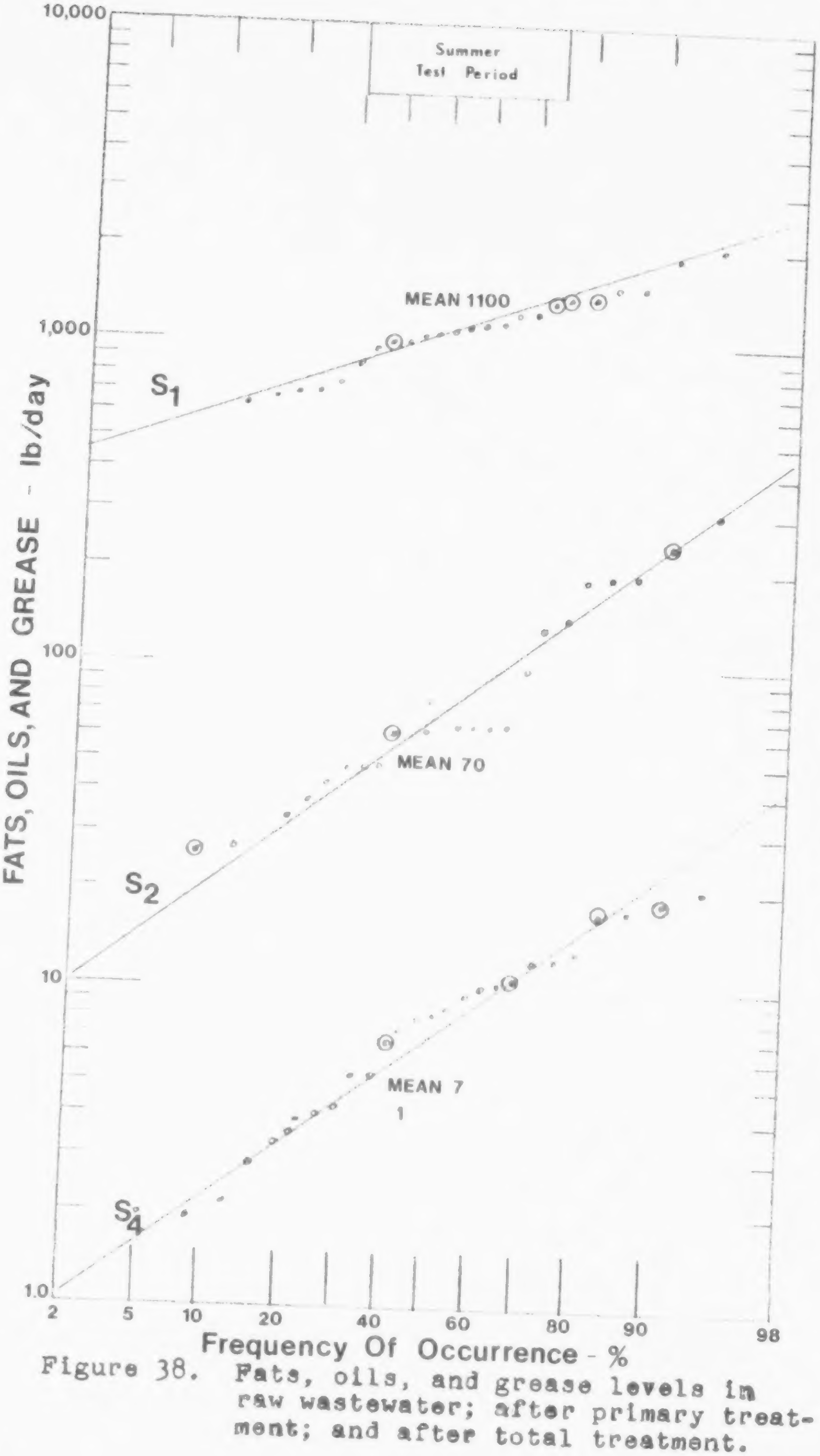

Figure 38. Fats, oils, and grease levels in raw wastewater; after primary treatment; and after total treatment.

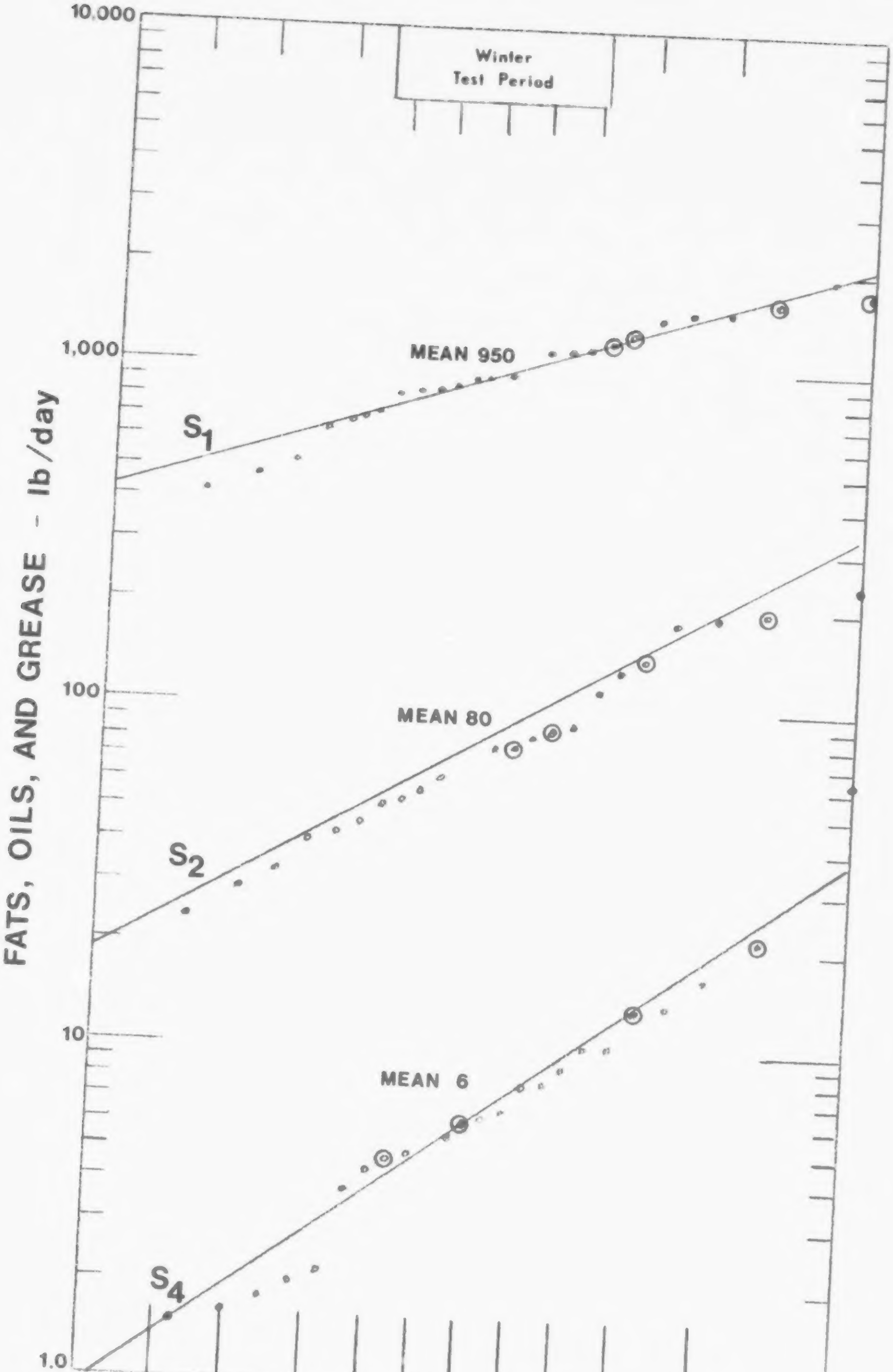

Figure 39. Fats, oils, and grease levels in raw wastewater; after primary treatment; and after total treatment.

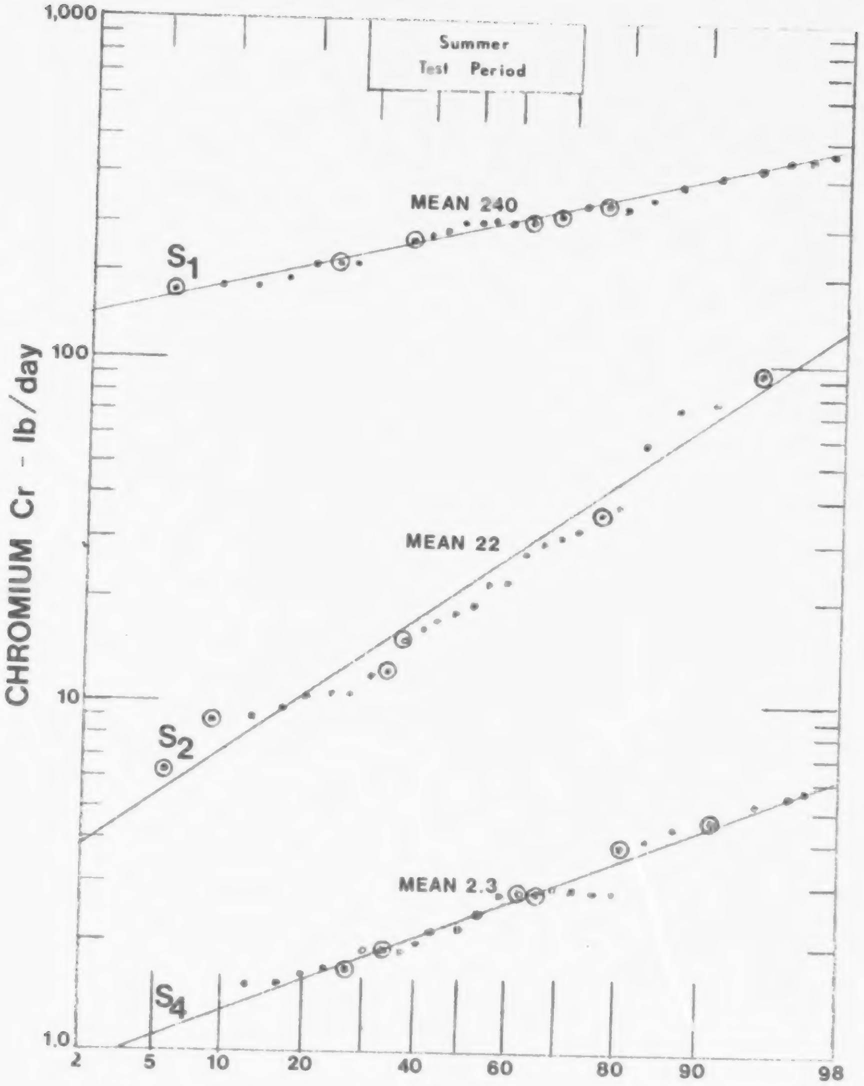

figure 40. Chromium levels in raw wastewater; after primary treatment; and after total treatment, expressed as Cr.

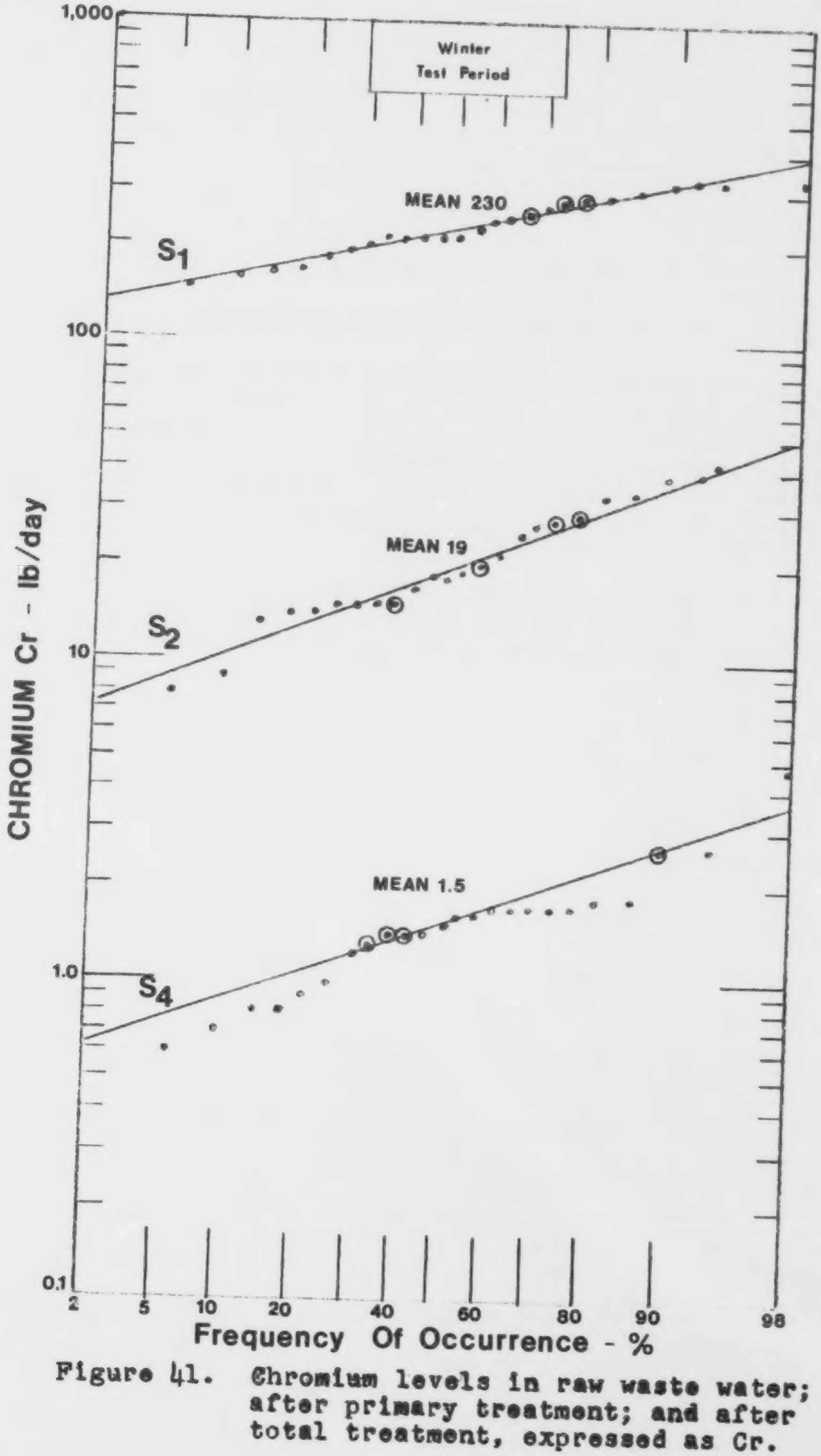

Figure 41. Chromium levels in raw waste water; after primary treatment; and after total treatment, expressed as Cr.

SECTION 8

CONCLUSIONS AND EVALUATIONS

CONCLUSIONS AS TO PARAMETER REMOVALS

The first objective of this demonstration grant was to determine the effectiveness of this treatment system in finite terms. One of the principal further objectives was to determine the effect of cold weather upon bacterial activity in the secondary portion. The data in tables 8 and 9 has been summarized to show the total pollutant removal efficiency of this wastewater treatment plant while operating under summer conditions as well as winter conditions. This summary follows:

TABLE 11. AVERAGE PERCENT OF POLLUTANT REMOVAL TOTAL TREATMENT* SUMMER AND WINTER TEST PERIODS

Pollutant	% Removal	
	Summer	Winter
BOD_5	99.1	97.6
Suspended solids	80.9	84.1
Nitrogen-total	94.7	83.5
TKN	94.1	87.4
Ammonia	96.4	74.6
Fats, oils and grease	98.8	99.0
Chromium	99.0	98.8

*On basis of differences between samples taken at S_1 and S_4.

It is evident from this table that winter operating conditions did reduce carbonaceous and nitrogenous biological activity noticeably but substantial reduction continued to occur.

BOD Removals

Cold weather has a substantial effect upon many biological wastewater treatment systems in lowering the efficiency of BOD removal. In this study the average BOD reduction during winter was only slightly less than in summer. In addition, Table 9 reveals that single-digit results in mg/l were frequently achieved in winter, thus indicating excellent resistance by the carrousel design to atmospheric conditions well below freezing.

Table 11 shows in excess of 97% removal of BOD regardless of seasonal conditions. The average residual BOD is shown by analysis to be on the order of 6 mg/l. This is one-fifth of the unofficial BAT standard. Obviously this wastewater treatment plant is very effective in reducing biological oxygen demand.

Suspended Solids Removal

Short of an actual freeze low temperatures would not be expected to be much of a deterrent to removal of suspended solids. Actually the record shows the removals to be a little better in winter than in summer, but examination of the data reveals that temperature was not a factor in the incidence of residual suspended solids as discharged.

Table 12 shows suspended solids to be in excess of the unofficial BAT requirements. Terminal removal is dependent upon the efficiency of the final clarifier. Obviously some additional fine tuning will be required but compliance seems to be attainable.

Nitrification - Denitrification

The data shows that the carrousel is capable of supporting nitrifying and denitrifying bacteria. The former converts nitrogenous compounds to nitrates, and the latter converts nitrates to free nitrogen. Analytical results reported in Table 8 and Table 9 bear this out. Some TKN removal occurs chemically in the primary section. The tables clearly show that ammonia nitrogen and organically bound nitrogen entering the carrousel at S_2 were substantially reduced in the ditch, more in summer than in winter. Table 9 also reveals that on some days during winter operation very low concentrations of NH_3-N and TKN did occur at S_4, indicating that lower average nitrification activity in winter may have been more attributable to occasional incidence of an unknown form of toxicity than temperature.

Conversion of nitrates to nitrogen is not only an interesting and perhaps unique feature of this system but it also has broad implications in the whole field of wastewater treatment. Support of denitrifying bacteria seems to be somewhat more difficult than that of the nitrifying strain. Additional study toward establishing a more stable environment for these organisms would certainly be worthwhile. Denitrifiers were rather late in developing during the summer period but they were extremely active and efficient during the winter period. Later on, after this grant project was completed, the denitrifiers were adversely affected for a time, but they have now returned. They may have been subjected to some form of chemical toxicity, or perhaps the balance of aerobic/anoxic conditions was not agreeable. Work is continuing to gain further insight.

Fats, Oils and Grease Removal

As with suspended solids the removal of fats, oils and grease would not seem to be very temperature dependent, and the results are consistent with this. Average removal was actually a little higher in winter than in summer but it is not possible to fix to this any real significance.

In comparison with unofficial 1983 BAT levels the average results are better than required, with residual pollutant in the effluent approximately 40% of that allowable by BAT. 99% removal is achieved.

Chromium Removal

Chromium is probably the most important parameter, from the point of view of removal, of any of the components of tannery effluent. Controversy exists as to the relative toxicity of tannery chromium discharged. Actually it exists entirely in the trivalent form and as such is highly insoluble at pH's encountered in a biological treatment system, but many investigators are skeptical and suspect that a portion may exist as or be converted to the hexavalent form which is highly toxic. The existence of chromium in this system at the residual level after primary treatment has never poisoned the bacteria in the secondary or limited biological activity in any way, thus indicating rather conclusively that it is all trivalent, virtually insoluble, and benign.

The analytical data shows a high degree of removal, 99% on the average, both summer and winter. In terms of kilograms discharged per kilogram of raw pelt the average amount discharged is within the BAT requirement.

SYSTEM EVALUATION AND DISCUSSION

The proposal for this grant states on page 20, Part IV-4e, Sampling and data collection procedures, that methods for evaluating the results of the project will consist of:

a. Evaluating the character of the final effluent in terms of attainment of BAT requirements.

b. Fixing the cost of operation while producing effluent at BAT levels in terms of:

    Cents per foot of finished leather product.

    Cents per pound of finished leather product.

    Cents per pound of BOD plus COD removed.

    Cents per pound of suspended solids removed, compacted and placed at final destination.

    Cents per pound of nitrogen removed.

The grant amendment dated August 23, 1976, added other means of evaluating the results. These are:

Page 5A, item 3C
Include the cost in cents per 1,000 gallons treated.

Page 5A, item 5
The grantee shall include a section which compares the demonstrated processes with other processes used for the same or similar purposes in the tanning industry and describe what changes in design or cost would be expected when applying the demonstrated technology to a typical cattle hide tannery. Specific items to be addressed are:

a. comparison on a cost-effective basis of the LectroClear with available information on conventional primary treatment or dissolved air flotation being utilized by the industry, or with the possibility of no primary treatment.

b. comparison of the performance and other data on the carrousel with available information on the unit in Oisterwijk, Netherlands treating tannery wastewaters.

c. based on the demonstrated design criteria and available information, make a preliminary design and cost estimate for installing the system at a typical cattle hide tannery in the U.S. to meet the 1983 guidelines.

In this section of the report the above specified means of evaluation will be dealt with in the order of listing, with the exception of item 5c, which will be detailed in a separate section. See Section 9.

ATTAINMENT OF BAT REQUIREMENTS

The BAT requirements for 1983 (unofficial) are compared in Table 12 with the results obtained during the summer and winter operating periods of the Winchester project. Compliance is achieved in almost every category except suspended solids, TKN in the winter, and fecal coliforms. The latter can be controlled only by disinfection. Chlorination has not been provided as a function of the treatment facility. Undoubtedly some chlorine generation occurs as a result of electrolysis in both the coagulation cell and the flotation basin but this was not evaluated. It may account for the lower incidence of coliform colonies during the first test period when electrolytic activity was greater. It is interesting to note that the average level of .40 kg of TKN per 1,000 kg of raw pelt in the treated wastewater during wintertime conditions, while in excess of BAT, represents an 87% removal of TKN from the raw wastewater.

TABLE 12. COMPARISON OF WINCHESTER EFFLUENT WITH BEST AVAILABLE TREATMENT STANDARDS FOR 1983 *

Pollutant	BAT maximum/day	BAT average of daily values for 30 consecutive days	Winchester summer conditions (25 days)		Winchester winter conditions (25 days)	
			max/day	ave/day	max/day	ave/day
BOD_5 **	3.20	1.60	0.47	0.29	0.86	0.36
Total suspended solids **	3.60	1.80	12.34	4.77	9.24	3.65
Chromium **	0.12	0.06	0.14	0.06	0.07	0.06
Oil and grease **	1.26	0.63	3.25	0.34	1.63	0.19
Sulfide **	0.012	0.006	-	-	-	-
TKN **	0.62	0.31	0.59	0.31	1.29	0.40
Fecal Coliforms/100 ml	400	no std.	660	-	7,000	-
pH	6.0-9.0	no std.	6.5-7.6		6.8-7.6	

* Federal Register Volume 39 Number 69 April 9, 1974. Promulgated but remanded. Par 42553

** Unit is kg/1000 kg raw pelt.

COSTS OF OPERATION

One of the study objectives was to determine the operating costs of producing treated effluent at BAT levels in terms of cents per foot of finished leather product, cents per pound of finished leather product, cents per pound of BOD_5 removed, cents per pound of suspended solids removed, compacted and placed at final destination, cents per pound of nitrogen removed, and cents per 1,000 gallons of wastewater treated.

Operating costs for the 12-month study period were as follows:

Plant personnel - - - - - - - - - - - -	$46,860.68
Chemical supplies and electricity - -	78,301.20
Repairs and equipment - - - - - - - - -	8,423.00
Total - - - - - - - - - - - - - - - - - -	$133,584.88

Production during the 12-month period was:

Skins produced (dozen) - - - - - - -	58,466
Skins produced (ft^2) - - - - - - - -	5,846,600

Cents per Foot of Finished Leather Product

The cost of producing BAT level effluent per foot of finished leather product is determined as follows:

Operating cost/year - - - - - - - - - -	$133,584.88
Skins produced (ft^2) - - - - - - - - -	5,846,600
Cost per square foot of product - - -	$.0228

Cents per Pound of Finished Leather Product

Cost of the BAT-level effluent per pound of finished leather product is determined as follows:

Operating cost/year - - - - - - - - - -	$133,584.88
Skins produced (dozen)- - - - - - - - -	58,446
Average weight per dozen (lb) - - - -	24
Total weight (lb) - - - - - - - - - - -	1,402,704
Total cost per pound - - - - - - - - -	$0.095

Cents per Pound of BOD Removed

Cost of removing BOD is determined as follows:

Operating cost/year - - - - - - - - - -	$133,584.88
Operating days/year - - - - - - - - - -	250
Operating cost/day- - - - - - - - - - -	$534

BOD removed/day (lb)	2,050
Cost/lb BOD removed	$0.26

Cents per Pound of Suspended Solids Removed, Compacted, and Placed at Final Destination

Cost for removing suspended solids, compacting them, and placing them at their final destination is determined as follows:

Operating cost/day	$534
Suspended solids removed/day (lb)	2,394
Cost/lb suspended solids removed	$.22

Cents per Pound of Nitrogen Removed

Cost for removing nitrogen is determined as follows:

Operating cost/day	$534
Nitrogen removed/day (lb)	272
Cost/lb nitrogen removed	$1.96

Cents per 1,000 Gal. of Wastewater treated

Cost per 1,000 gal of wastewater treated is determined as follows:

Average daily flow (gal)	301,000
Operating cost/day	$534
Cost/1,000 gal wastewater treated	$1.77

OPERATING COST OF MICROBUBBLE GENERATION BY ELECTROLYSIS, DISPERSED AIR, AND DISSOLVED AIR.

Elsewhere in this report it is stated that the LectroClear electrolytic cell, as a primary source of microbubbles, was discontinued for two reasons; an inordinate amount of difficulty was encountered with maintaining electrodes in the coagulation cell operational, and clear evidence was established that the electrolytic generation of microbubbles could not compete cost-wise with dispersed air generation.

Electrolysis

The cost of operation of the LectroClear electrolytic cell, the original principal LectroClear microbubble generator is determined as follows:

Design amperage requirement	2,900
Design voltage requirement (DC)	6
Kilowatts required per hour	17.4

Power cost per kilowatt hour	$0.035
Cost of power per hour	$0.609
Hydraulic flow rate (gpm)	300
Cost per 1,000 gallons	$.034

Dispersed Air

The cost of operation of the dispersed air generator is determined as follows:

Design power requirement (hp)	2
Kilowatts per horsepower	0.746
Power cost per kilowatt hour	$0.035
Cost of power per hour	$0.052
Hydraulic flow rate (gpm)	300
Cost per 1,000 gal.	$.003

Dissolved Air[12]

The estimated cost of operation of dissolved air flotation for this application, 300 gpm throughput with 50% recirculation for microbubble formation is calculated as follows:

Design rate of flow (gpm)	300
Recirculation rate - 50% (gpm)	150
Back pressure for air solubilization (psi)	60
Required pump HP	7
Kilowatts required per hour	5.2
Power cost per KWH	$0.085
Cost of power per hour	$0.182
Hydraulic flow rate (gpm)	300
Cost per 1,000 gallons	$0.010

These calculations show that the cost of electrolytic generation of microbubbles is on the order of eleven times that of dispersed air generation. Considering this, along with less than adequate electrode reliability, leads to rejection of the electrolytic concept as a principal source of encouragement to flotation. Likewise the calculated cost of operation of a system designed to provide microbubbles by means of dissolved air for floc flotation is in excess of the cost determined by actual operation for dispersed air.

TABLE 13. COMPARISON OF COSTS OF OPERATION OF SYSTEMS TO PROVIDE MICROBUBBLES FOR A FLOTATION SYSTEM FOR SUSPENDED SOLIDS SEPARATION

Microbubble generation mode	Cost of operation per 1,000 gals treated
LectroClear	$.034
Dissolved Air	$.010
Dispersed Air	$.003

CONSIDERATION OF THE POSSIBILITY OF NO PRIMARY TREATMENT

The possibility of elimination of primary clarification, and dependence upon a biological treatment system plus a final clarifier only has been considered. The existence of a relatively large amount of chromium in the non-clarified wastewater as a substance potentially toxic to activated sludge bacteria has been a deterrent to experimental by-pass of the primary section. Other toxic chemicals which may be absorbed in the agglomerated precipitates in the primary section and removed there are suspected of being present in the raw wastewater also, which could interfere with bacterial activity in the carrousel, although these were not identified in this study. Chromium and alumium hydroxides formed by pH adjustment to 7.5 to 8.5 to remove them, as well as to provide agreeable environmental conditions for bacteria in the secondary, are gelatinous precipitates which do not rapidly settle to a reasonably compact bottom sludge layer. These facts, and the high incidence of emulsified fats and oils encountered in the waste stream, led to a laboratory bench scale testing decision in the design stage that removal of the suspended solids introduced to the system would best be removed by flotation. These considerations, in addition to the compaction feature provided by microbubbles continuously rising, raising and dewatering the sludge blanket atop the flotation basin, have adequately demonstrated the desirability of maximum separation of suspended solids in a primary clarification section prior to activated sludge treatment.

COMPARISON OF THE PERFORMANCE OF THIS CARROUSEL WITH ONE AT OISTERWIJK, NETHERLANDS[13]

A full scale carrousel has been in operation at Oisterwijk, Netherlands since 1973 treating tannery wastewater. The tannery is in the category 1 classification, chrome tan-hair burn, and is of medium size, processing not much more raw hide weight (55,000 lb/day) than the Winchester tannery (43,200 lb/day green salted shearlings). Water usage at 0.475 mgd is in direct proportion on a green hide or skin weight basis to the volume used at Winchester (.350 mgd). Following is a table showing waste loadings to the

Oisterwijk carrousel as well as the Winchester carrousel, and the degree of removal of pollutants affected significantly by secondary treatment, BOD, NH_3-N and total N.

TABLE 14. COMPARISON OF CARROUSEL TREATMENT EFFICIENCIES WINCHESTER, N. H. vs. OISTERWIJK, NETHERLANDS

Treatment plant	Influent mg/l	Effluent mg/l	Removal %
Winchester BOD_5	317	6	98
Oisterwijk BOD_5	1,100	20	98
Winchester-NH_3-N	32	5	84
Oisterwijk-NH_3-N	264	248	6
Winchester-total-N	107	12	89
Oisterwijk-total-N	408	270	34

The loadings to the carrousel at Oisterwijk are far greater than to the carrousel at Winchester as shown above. This may be due to removal of BOD and nitrogenous material in the Winchester primary section, whereas it is the understanding that the Oisterwijk treatment plant does not have primary coagulation and clarification.

Comparison of the efficiency of each in terms of removal of parameters clearly shows superiority of the Winchester operation. Further proof of this is demonstrated by quoting from a recently issued DRAFT of an E.P.A. development document for the leather tanning and finishing industry.[13] Investigators who prepared this document state, on lines 6863 through 6866, "This (analysis of data) indicates that this (Winchester) activated sludge system produced better results than the Netherlands (Oisterwijk) application, including demonstration of insensitivity to winter temperatures in removal of carbonaceous oxygen demand (BOD_5) and nitrogenous oxygen demand (ammonia) by nitrification."

The Oisterwijk application, according to analytical data available, was not very effective in nitrification and denitrification. Experience at Winchester at times other than the demonstration periods has shown that denitrification in particular is a sensitive process. It is also possible that the Oisterwijk facility was not being operated with any emphasis upon nitrification-denitrification at the time the above data was recorded. More operating background and understanding is needed to further establish reliability at high levels of nitrification-denitrification.

SECTION 9

APPLICATION OF THE SYSTEM TO CHROME-CATTLEHIDE AND VEGETABLE-CATTLEHIDE TANNERIES

CONSIDERATION AND COMPARISON OF PROCESSES

Three of the seven categories of tanneries relate to full-scale cattlehide processing - including hair removal, tanning, coloring and fatliquoring, and finishing. The three categories are cattlehide tanneries that (1) pulp hair and chrome tan, (2) save hair and chrome tan, and (3) save hair and vegetable tan.

Few if any chrome tanneries save hair. More and more the mode has been to soak, wash, and hair-burn using strong sodium sulfide liquors. Most tanneries operating this way reclaim sulfide liquors and separate pulped hair solids from those solutions, directing the solids to land-fill, thus keeping as much as possible of those materials out of the waste stream. Similarly systems have been developed by most chrome tanners to conserve chromium by precipitation and reuse or by recycling of chrome tan liquors, and most are conscious of the need for water conservation, not only from the point of view of initial cost, but in consideration of the effects of wasteful dilution, and the hydraulic load cost of disposal and sewerage treatment.

In a different but similar manner most vegetable tanneries employ a hair save process. This system uses much less sulfide and produces a valuable by-product in the form of cattle hair. Not unlike chrome tanners, vegetable tanners have been able to reduce or eliminate some process steps which formerly required much water.

The net result of these in-plant activities has been to reduce high potency waste liquors to levels which are not so different from those encountered at the shearling tannery. Because a shearling tannery is not typical, since it does not process cattlehide and has no beamhouse, transfer of identical wastewater treatment technology is not possible. Nevertheless, very real similarities do exist in the nature of the respective tannery discharges, which lead to speculation that adaptations should be explored.

COMPARISON OF WASTEWATERS

In order to rather definitely establish the similarity the following table of typical analyses of wastewater from these A. C. Lawrence tanneries, all of which are considered to be more or less representative of complete tanning operations in their respective categories are presented.

TABLE 15. TYPICAL TANNERY WASTEWATER ANALYSES

Parameter	Category 1 Cattlehide Chrome tan-pulp hair South Paris, Maine mg/l	Category 3 Cattlehide Veg tan-save hair Hazelwood, N.C. mg/l	Category 7 Shearlings Chrome tan Winchester mg/l
BOD	1,630	686	812
Suspended solids	2,718	1,080	1,150
Total solids	5,620	5,314	14,000
Calcium-Ca	649	550	400*
Fats, oils, greases	580	201	450
pH	10.9	9.9	5.1
Chromium-Cr	187	-	99
Ammonia-N	14	73	32
TKN-N	126	179	75
Volume-mgd	0.8	0.3	0.3
Raw hide or pelt lb/day	130,000	52,000	41,500
Water usage-gal/lb hide	6.1	5.8	6.9

*Added at treatment plant

Examination of this table shows that there is a remarkable similarity in the nature of the wastewater from each. The volumes are not the same, of course, but the significant differences in pollutant strengths are on the order, for the most part, of about 2X. Total volume is considerably greater for the side leather tannery since this is a function of capacity. The figure of 14,000 mg/l for total solids in the Winchester column reflects the very large comparative amount of curing salt in and on a raw pelt or entrapped in the wool, and the use of long brine floats in paddle pits while processing shearlings as opposed to short brine floats in drums for hides.

It seems in order then, to take the stance that this treatment system, with some modifications, is suitable for any tannery. One of the requirements of this demonstration project is to prepare a preliminary design and cost estimate for a system suitable for a typical U.S. cattlehide tannery to meet 1983 BAT guidelines. This exercise will include a system for a chrome tan-pulp hair category 1 tannery, and a system for a vegetable tan-save hair category 3 tannery. Since A. C. Lawrence Leather Company operates and has intimate knowledge of fairly typical tanneries processing cattlehides in both of these categories those tanneries will comprise the basis for the designs.

Comparison of parameters, as in Table 15, seems to impart validity to the statement that the only apparent differences between wastewater a treatment facility suitable for a hide tannery, and a shearling tannery, would be; (1) size, (2) provision for initial sedimentation to remove some of the heavy beamhouse and tanhouse solids before intermixing the two streams and (3), proper built-in precaution, particularly in the case of the chrome-pulp hair tannery, to consistently maintain the pH in the mixed beamhouse-tanhouse liquor above 8.5 to prevent evolution of hydrogen sulfide as an obnoxious and perhaps potentially lethal gas. These considerations are incorporated in the designs.

PRELIMINARY DESIGN AND COST DEVELOPMENT FOR A WASTEWATER TREATMENT PLANT FOR A CHROME TAN-PULP HAIR CATEGORY 1 CATTLEHIDE TANNERY

This exercise is addressed by expanding the detailed information on the Winchester treatment plant components as presented in Section 3 of this report, and cost information for the complete system presented as Appendix B. Two reports, entitled "Supplemental Report on Combined Wastewater Treatment Facilities, Paris Utility District, South Paris, Maine" by Whitman and Howard, Inc. Boston, Mass. and the other, "Activated Sludge Treatment of Chrome Tannery Wastes" by A. C. Lawrence Leather Co., South Paris, Maine, F.W.P.C.A. Publication ORD-5 are used for background information in developing the chrome-tan pulp hair preliminary design. Costing of components is estimated by comparing flows and parameter loadings at South Paris and Winchester where applicable, and arriving at a reasonable estimation. No attempt has been made to provide engineering designs or obtain equipment or construction contractors bids for any item. Costing of concrete construction has been estimated by examination of costs presented in the above documents, and has been determined to be about $8.00 per cubic foot of total tank volume, after updating 1974 and 1976 prices by compounding at 8% per year.

See Figure 42 for schematic diagram.

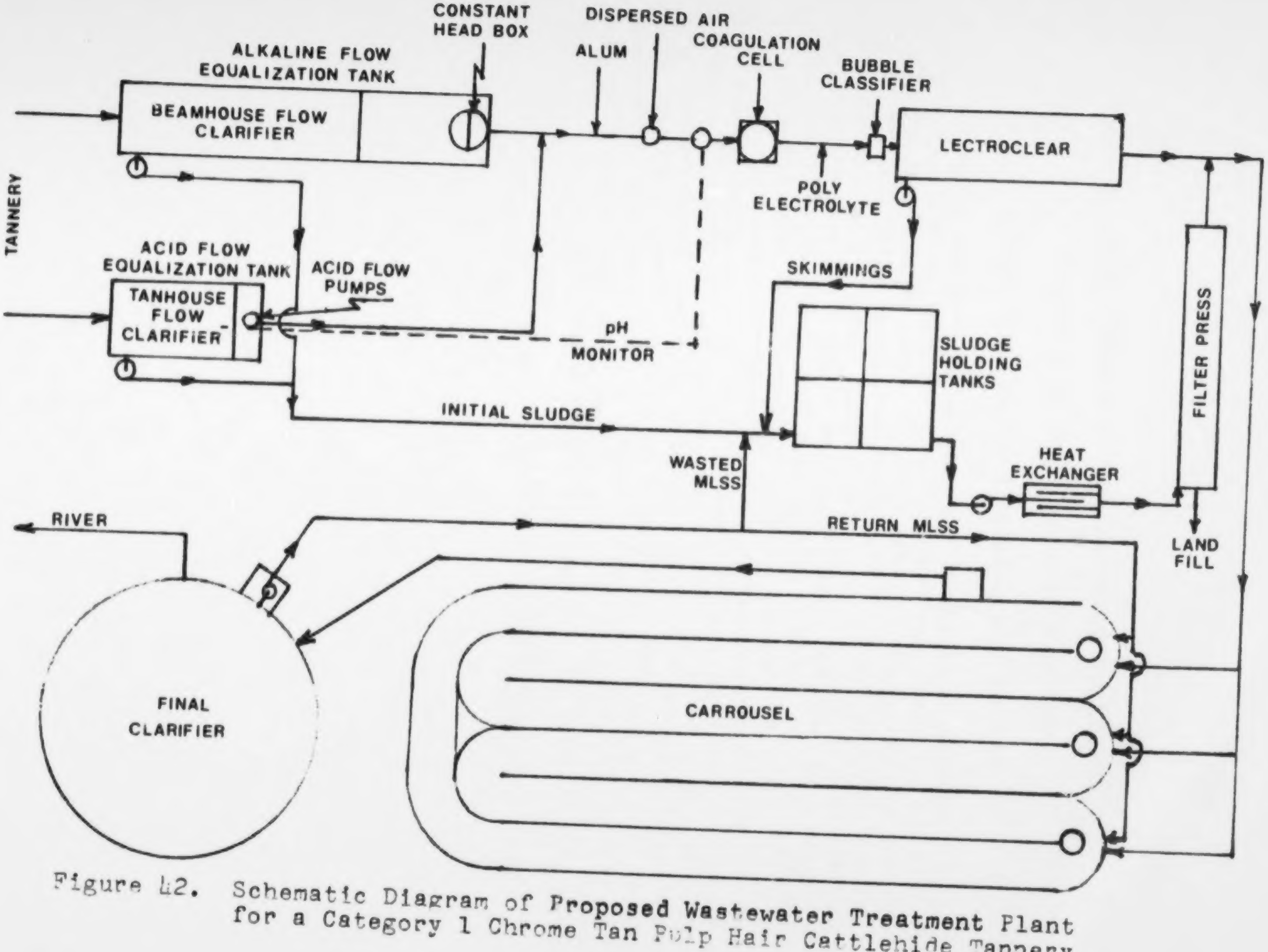

Figure 42. Schematic Diagram of Proposed Wastewater Treatment Plant for a Category 1 Chrome Tan Pulp Hair Cattlehide Tannery

Basic Design Parameters - Chrome Tan, Pulp-Hair WWTP

Total flow (mgd) - - - - - - - - - - - - - - - - - - 0.8
Beamhouse flow (mgd) - - - - - - - - - - - - - - - 0.575
Tanhouse flow (mgd) - - - - - - - - - - - - - - - - 0.225
Pollutant loadings - see Table 15.
Treatment plant operating day (hrs) - - - - - - 20
Equalized beamhouse flow (gpm) - - - - - - - - - 479
Equalized tanhouse flow (gpm)- - - - - - - - - - 200
Total equalized treatment plant operating flow (gpm) - - - - - - - - - - - - - - - - - 679

Design and Cost Estimation of Components

Coarse Screening

This is not necessarily a part of a treatment system per se. Coarse screening at the point the effluent stream emanates from the tannery is essential whatever the destination may be, for protection of transmission lines if nothing else. Therefore, this item is not being included as such, but provision for removal of solids which can be separated by simple sedimentation is included in the plans for the alkaline and acid wastewater holding tanks.

Raw Wastewater Pumps

These are needed only in the event that grades are not adequate for gravity flow, and are related to transmission rather than treatment. In most cases the holding tanks can be located below grade if necessary, and the constant flow pumps will provide whatever elevation is needed.

Holding and Equalizing Tanks

The wastewater flow from the tannery arrives at the treatment plant in two streams, beamhouse flow which is highly alkaline because of its lime and sodium sulfide content, and tanhouse flow which is acidic. Both flows are erratic because each is dependent upon batch operation dumps. Also both flows may contain suspended solids in sizes ranging from fine to gross. In view of difficulties encountered with entrained solids at existing treatment plants where their presence was not sufficiently recognized during the design stage, it is considered essential to include solids removal in the holding and equalizing tanks for each waste stream in this exercise. This step will help to also bring the character of the combined flows more into line with the single Winchester tannery effluent stream by initially removing an appreciable amount of undissolved lime. The tanks have the same over-all holding capacity as designed for South Paris and found to be adequate in practice, but include travelling bottom scrapers in the major portion of each to direct sedimented solids to a sludge withdrawal well at the entering end, very similar to a standard rectangular catch basin.

Beamhouse flow holding, equalizing, and clarifying tank

This tank is envisioned to be of concrete, rectangular, and is divided into two sections by a wall located two thirds of the total length of the tank from the entering end. The wall extends from the top of the tank to the bottom, with a three inch horizontal opening in the wall across the full width of the tank, two feet from the bottom of the tank. This horizontal slot opening allows flow to pass from the first section into the second section where the constant flow head box is located, whilst minimizing back-passage of turbulence and discouraging wash-through of solids at times when the liquid level may be low. The aforementioned scraper flights are located in the first section, travelling in the direction counter to flow across the bottom, thence vertically upward to near the top of the tank, horizontally in the direction of flow across the top of the tank, and vertically downward to the beginning. In order to avoid excessive length for the wooden flights the width of the tank should not exceed twenty feet.

Design parameters

Detention time (hrs) - - - - - - - - - - - - - - - 10
Beamhouse flow (mgd) - - - - - - - - - - - - - - 0.575
Width of tank - see above (ft) - - - - - - - -max 20

Sizing and specifications

Construction - concrete
Volume - $\frac{10}{24}$ x 575,000 (gal) - - - - - - - - 239,000
Constant-gal/ft^3 - - - - - - - - - - - - - - 7.5
Volume (ft^3) - - - - - - - - - - - - - - - - 32,000
Width (ft) - - - - - - - - - - - - - - - - - 20
Length (ft) - - - - - - - - - - - - - - - - 100
Depth (ft) - - - - - - - - - - - - - - - - - 16

Cost estimate

Estimated unit cost - see above (ft^3)- - - - $8.00
Volume (ft^3) - - - - - - - - - - - - - - - - - 32,000
Construction cost - - - - - - - - - - - - - - -$256,000
Total cost including sedimentation equipment (est) - - - - - - - - - - - - - $275,000

Tanhouse flow holding, equalizing, and clarifying tank

This tank is also envisioned as being constructed of concrete, rectangular, and of the same total concept as the beamhouse flow tank, except that it is smaller, and the second section would not contain a constant flow head box, but would be the location of the tanhouse wastewater flow pumps.

Design parameters	
Detention time (hrs)	10
Tanhouse flow (mgd)	0.225
Width of tank (ft)	max 20
Sizing and specifications	
Construction - concrete	
Volume - $\frac{10}{24}$ x 225,000 (gal)	94,000
Constant - gal/ft^3	7.5
Volume (ft^3)	12,500
Width (ft)	20
Depth (ft)	16
Length (ft)	40
Cost estimate	
Estimated unit cost (ft^3)	$8.00
Volume (ft^3)	12,500
Construction cost	$100,000
Total cost including sedimentation equipment (est)	$115,000

Constant Flow Equipment

The concept of constant flow through the treatment system was incorporated into the design of the Winchester, W.W.T.P. Pumps in the holding tank elevate wastewater to an overflow weir box of special design (see Section 3), from whence it flows to and through the system at a constant rate. This mode of operation simplifies process control since all of the components of the primary treatment section operate in unison without adjustment for flow variations. The primary section operates either all-on or all-off, depending upon the availability of effluent to be treated, thus allowing constant settings for dosing pumps and the dispersed air microbubble generator, and eliminating wear and tear when flows are low or non-existent. The on-off control is provided in this situation through level sensing switches located in the beamhouse flow holding tank, which activate or interrupt the constant head supply pumps and the tanhouse flow pumps according to the availability, in this case, of alkaline tannery effluent.

Constant flow head box

See Section 3

Design parameter

Horizontal cross section (gal/ft^2/min) - - - - - - - 32

Sizing of vessel

Total volume of beamhouse flow (gpd) - - - - - - - - 575,000

Design treatment plant operating day (hr) - - - - - 20

Flow rate through weir box (gpm) - - - - - - - - - - 479

Cross sectional area needed @ 32 gal/ft^2/min - (ft^2) 15

Diameter (ft) - - - - - - - - - - - - - - - - - - - 4.5

Depth (ft) - 9

Cost estimate

Fiberglass lay-up - - - - - - - - - - - - - - - - - $750

Constant flow supply pumps - beamhouse flow holding tank

These are submerged pumps to be located near the bottom of the beamhouse flow holding tank at the end opposite from the flow entrance. They elevate the beamhouse wastewater to the constant-flow head box and thence into the treatment system. Two pumps, each capable of supplying full flow are included here to avoid interruption in case of single pump failure.

Design parameter

Flow rate (gpm) - - - - - - - - - - - - - - - - - - 479

Sizing and pump specification

Capacity (gpm) - - - - - - - - - - - - - - - - - - - 600

Manufacturer - Flyght Corp. Norwalk, Conn.

Model No. 6- CP - 3126

Motor HP - 9.4

Cost estimate

Pumps - 2 $1,500 each - - - - - - - - - - - - - - - $3,000

Tanhouse Wastewater Flow Pumps

Tanhouse waste will be collected in the tanhouse flow holding tank and dispensed therefrom at a constant rate as long as alkaline waste is available unless interrupted by the pH sensing device located in the main flow line downstream of the constant flow head box, signalling that the danger condition of pH 9.0 is being approached. It is estimated that the constant flow rate for this material will be 200 gpm, which would deplete the design supply in 18.75 hours, slightly sooner than the design supply of alkaline beamhouse waste from the beamhouse flow holding tank. Actual practice or pilot plant work might disclose that a higher rate of acid waste flow could be tolerated but it seems important to have the two waste streams become exhausted at about the same time. Two pumps, each capable of supplying full flow are specified here, as in the beamhouse line, to avoid interruption in case of single pump failure.

Design parameter	
Flow rate (gpm)	200
Sizing and specification	
Capacity - each (gpm)	200
Manufacturer - Flyght Corp. Norwalk, Conn.	
Model No - 4 - CP - 3105	
Motor HP	5
RPM	1,750
Cost estimate	
Pumps - 2 $1,000 each	$2,000

pH Sensing for Acid Waste Flow Control

As noted in the foregoing this sensor would function only as a safeguard against development of an acid condition in the mixed wastewater flow.

Design parameters	
pH range	7.5 to 11
Power interruption level (pH)	9.0
Specifications	
Manufacturer - Beckman Instrument Co. Cedar Grove, N. J.	
Model No. - 940 pH analyzer	
Special feature - 10% dead band @ pH	8.0 to 9.0
Cost estimate	
Instrument	$1,500
Remote sensor connection - 150 ft.	200
Total	$1,700

Dosing Pump - Alum

Alum is used to develop agglomerated flocculation which not only aids in entrapping and removing finely divided suspended solids, but also aids in entrapping microbubbles to enhance flotation. The alum is purchased and used in 45% wt. solids solution, sp. gr. 1.330.

Design parameter

1,000 mg/l to be added to combined beamhouse-tanhouse flow

Sizing and pump specification

Equalized beamhouse flow (gpm)	479
Equalized tanhouse flow (gpm)	200
Total equalized flow (gpm)	679
Weight of flow (lb/gal)	8.5
Weight of flow (lb/min)	5,770
Weight of alum @ 1,000 mg/l (lb/min)	5.77
Weight of stock alum solution needed @ 45% solids (lb)	12.82
Weight of stock alum solution (lb/gal)	11.1
Volume of stock alum solution needed (gpm)	1.15
Pump capacity needed (gpm)	± 1.15

Manufacturer - Liquiflo Equipment Co.
Warren, N. J.

Series 34 3 gpm ½ in. 316 SS

Motor HP (DC)	0.75
Speed - variable. Max rpm	1,725

Cost estimate

Pump and motor	$250

Dispersed Air Generator

See Figure 5.

Microbubbles are used to provide flotation for the suspended solids removal principle used in this treatment system. Dispersed air is the least expensive means for providing the same, see section 8.

Design paramter

Ft^3 of air/100 gal of flow	0.5
Total equalized flow rate (gpm)	679

Sizing and specifications.

Manufacturer - Greey Corp.
Toronto, Canada

Model No. 6 - LBC - 300 316 SS

Motor HP	3

Cost estimate

Generator with motor, complete	$4,500

Coagulation Cell

See Figure 6.

This unit is used to provide detention time to allow microbubbles and suspended floc to become intimately associated, thus enhancing flotation.

Design parameter

Effective residence time 2 minutes

Sizing and specifications.

Total equalized flow rate (gpm) - - - - - - - - - - - -	679
Cell volume required for 2 min. flow (gal) - - - - -	1,358
Cell volume required for 2 min. flow (ft^3) - - - - -	181
Diameter of top section (ft) - - - - - - - - - - - - -	7.5
Depth of top section (ft) - - - - - - - - - - - - - - -	2.5
Width of bottom section (ft) - - - - - - - - - - - - -	8.0
Length of bottom section (ft) - - - - - - - - - - - - -	8.0
Depth of bottom section (ft) - - - - - - - - - - - - -	2.0

Manufacturer - Local sheet metal fabricator

Cost estimate

Same as 1976 updated @ 8% per year (est) - - - - - -	$10,500

Dosing Pump - Polyelectrolyte

This pump is used to continuously add about 12 mg/l of polyelectrolyte in 0.2% solution to the waste stream to aid flocculation and flotation.

Design parameter

12 mg/l to be added to combined flow.

Polyelectrolyte solution strength - 0.2%

Sizing and specifications.

Total equalized flow rate (gpm) - - - - - - - - - - - -	679
Weight of flow (lb/gal) - - - - - - - - - - - - - - - -	8.4
Weight of flow (lb/min) - - - - - - - - - - - - - - - -	5,700
Weight of polyelectrolyte needed @ 12 mg/l (lb) - - -	0.068
Solution strength (%) - - - - - - - - - - - - - - - - -	0.2
Weight of solution needed/min (lb) - - - - - - - - - -	34
Factor - lb/gal @ sp. gr. 1.015 - - - - - - - - - - - -	8.5
Volume of solution needed (gpm) - - - - - - - - - - - -	4

Pump capacity needed (gpm) - - - - - - - - - - - - - - 4

Manufacturer - Liquiflo Equipment Co.

Series 36 5 gpm 3/4 in. 316SS

Motor (HP) - 0.75DC

Variable speed, 1,725 rpm max.

Cost estimate

Pump and motor (est) - - - - - - - - - - - - - - - - - $300

Bubble Classifier

See Figure 7

This unit is an open top, rectangular, steel tank through which the waste stream is passed, after introduction of microbubbles, to allow oversize bubbles to escape before entering the flotation basin. Large bubbles disrupt the floating sludge blanket at the entering end of the LectroClear tank.

Design parameter

Surface area (ft^2/100 gpm) - - - - - - - - - - - - - - 3

Depth (ft/100 gpm) - - - - - - - - - - - - - - - - - - 1

Sizing and specifications

Total equalized flow rate (gpm) - - - - - - - - - - - 679

Surface area - $\frac{679}{100} \times 3$ (ft^2) - - - - - - - - - - - - 20

Length (ft) - 5

Width (ft) - 4

Depth - $\frac{679}{100} \times 1$ - 7

Manufacturer - Local sheet metal fabricator

Cost estimate

Tank complete (est) - - - - - - - - - - - - - - - - - - $750

LectroClear Solids Flotation Basin

See Figure 8

For description see Section 3

Design parameters

Surface area - ft^2/100 gpm - - - - - - - - - - - - - - 100

Vertical cross section perpendicular to direction of flow - ft^2/100 gpm - - - - - - - - - - - - - - - 15

Width - maximum (ft) - - - - - - - - - - - - - - - - - 20

Electrode density - number/100 gpm - - - - - - - - - 20

Sizing and specifications

Total equalized flow rate (gpm)	679
Area of vertical cross-section @ 15 ft^2/100 gpm (ft^2)	102
Depth of vessel, say (ft)	6
Width of vessel (ft)	17
Surface area @ 100 ft^2/100 gpm (ft^2)	679
Length of vessel (ft)	40

Manufacturer - Local machinery fabricator

Cost estimate

Cost of Winchester LectroClear (1976)	$31,200
Update for 1978 @ 8% per year	$35,000
Volume of Winchester unit (ft^3)	2,100
Volume of unit sized as above (ft^3)	4,080
Comparative size (x)	1.94
Comparative cost of unit (1978)	$67,900
Electrodes needed	136
Cost of electrodes, each	$95
Total cost of electrodes	$12,920
Total cost of flotation basin, installed (est)	$80,820

Current Rectifier

Direct current is required for microbubble generation by electrolysis in the LectroClear flotation basin.

Design parameter

2,600 amperes at 7 volts, D.C.

Sizing and specifications

Manufacturer - Oxymetal Industrial Corp., Warren, Mich.

Model - Udalite No. 4 MDV-5000

Type SASS e 460V

Water cooled

Cost estimate

Winchester cost (1976) including switches and wiring, installed	$10,500
Estimated total cost updated to 1978	$12,250

Skimmings Pump

Floated solids in the LectroClear unit are skimmed off and directed into a receiving tank, see figure 8, from which they are pumped to sludge holding tanks.

Design parameters

Open impeller trash pump design.

Capacity 2 times Winchester unit.

Sizing and specifications

Manufacturer - Gorman Rupp Co.

4 inch intake, 3" discharge

Motor 3 HP, 1750 rpm, direct connected

Cost estimate

Pump, installed	$1,500

Solids Slurry Pumps

Solids separated by sedimentation in the two holding tanks have to be transferred to the sludge holding tank to be compacted along with skimmed solids from the LectroClear and wasted solids from the carrousel. These will be activated by timers. Three pumps are needed, one at each initial clarifier, beamhouse and tanhouse, and a third for a spare. The advantage of standardization calls for specifying three alike.

Design parameters

Vaughn chopper pumps

Corrosion resistant construction

Sizing and specifications

Total volume of beamhouse flow (mgd)	0.575
Suspended solids removed by sedimentation (mg/l) (est)	500
Constant (lb/gal)	8.5
Weight of beamhouse flow (lb/day)	4,887,500
Weight of suspended solids removed (lb/day)	2,445
Weight of solids slurry @ 1% solids (lb/day)	244,500
Constant (lb/gal)	8.5
Average pumping rate @ 20 hr. day (gpm)	24

Total volume of tanhouse flow (mgd)	0.225
Suspended solids removed by sedimentation (est) (mg/l)	400
Weight of tanhouse flow (lb/day)	1,912,500

Weight of suspended solids removed (lb/day) - - - - 760

Weight of solids slurry @ 1% solids (lb/day)- - - - 76,000

Weight of slurry (lb/gal) - - - - - - - - - - - - - - 8.5

Volume of tanhouse flow solids slurry (gpd) - - - - 8,950

Average pumping rate @ 20 hr. day (gpm) - - - - - - 7.5

Number of pumps required - 3 Interchangeable

Manufacturer - Vaughn Co., Inc.
Montesano, Wash.

Model 150. Motor 5 HP, 1,750 rpm

Cost estimate

Pumps, each $3,500 - - - - - - - - - - - - - - - - - - $10,500

Sludge Storage Tanks

These tanks are used to accumulate and store sludge during the entire wastewater flow period so that the filter press can be operated mostly during the normal working day.

Design parameters

Storage capacity - 28 hrs.

Stirrers for uniformity and solids suspension

Sizing and specifications

Volume of flow in this W.W.T.P. (mgd) - - - - - - - 0.8

Volume of flow in Winchester W.W.T.P. (mgd) - - - - 0.3

Factor for flow-increase (x) - - - - - - - - - - - - 2.7

Suspended solids analysis, combined wastewater, this W.W.T.P. (mg/l) - - - - - - - - - - - - - - - - 2,718

Suspended solids analysis, raw wastewater, Winchester (mg/l) - 1,295

Factor for suspended solids-increase (x) - - - - - - 2.10

Volume of sludge generated at Winchester, see table 9 (gpd) - - - - - - - - - - - - - - - - - 18,000

Estimated sludge volume generated this W.W.T.P. 18,000 x 2.7 x 2.1 (gpd)- - - - - - - - - - - - - 102,060

Estimated sludge volume - 28 hrs (gal) - - - - - - - 120,000

Number of tanks needed - - - - - - - - - - - - - - - 4

Construction - reinforced concrete, rectangular with stirrers.

Size of tanks, each

Volume (gal)	30,000
Volume (ft^3)	4,000
Depth (ft)	14
Width (ft)	18
Length (ft)	18

Cost estimate

Estimated cost of rectangular concrete tank construction (ft^3)	$8
Estimated cost of each tank	$32,000
Estimated cost of four tanks	$128,000
Estimated cost of four tanks with stirrers (est)	$150,000

Sludge Compaction

Compaction in this exercise calls for the use of a filter press, thus requiring a special charging pump, and a heat exchanger to improve the rate of filtration.

Sludge compaction pumps

Design parameters

Sand Piper, air actuated, or equivalent

Maximum delivery pressure (psi)	100

Sizing and specifications

Total volume of sludge (gal/day)	102,600
Sludge compaction operating day (hr)	16
Sludge pump operating time (hrs)	12
Average rate of sludge flow to filter press (gpm)	142.5
Peak rate of sludge flow to filter press (start of batch) (gpm)	300
Pump capacity required (gpm)	300

Cost estimate

Manufacturer - Warren Rupp Pump Co.,
Mansfield, Ohio

Model no. - SA3A

Number required @ 300 gpm	2
Estimated cost, each	$1,400
Total cost	$2,800

Filter press

According to information available the plate and frame filter press is capable of dewatering sludge to a greater degree than any other equipment designed for that purpose. Maximum dewatering is economically essential.

Design parameters

Solids content of press cake (%)	35

Sizing and specifications

Total volume of sludge, Winchester (gpd)	18,000
Total volume of sludge, this unit (gpd)	102,600
Factor of size increase (x)	5.7
Total filter area, Winchester filter press (ft^2)	2,400
Filter area needed, this unit (ft^2)	13,680

Cost estimate

Cost of Winchester filter press, installed 1976	$55,000
Cost of Winchester filter press, installed 1978	$64,150
Estimated cost of unit 5.7 times larger	$365,650

Heat exchanger

Design parameters

Stainless steel construction (316)

Temperature increase - 25°C to 65^{c}C

Sizing and specifications

Contact area of Winchester unit (ft^2)	88
Peak rate of sludge flow Winchester unit (gpm)	50
Peak rate of sludge flow this unit (gpm)	300
Factor of increase in contact area needed	6
Estimated contact area, this unit (ft^2)	528

Cost estimate

Cost of Winchester unit 1976	$4,000
Cost of Winchester unit 1978	$4,665
Cost of unit 6 times larger	$28,000

Air Compressor

Since the sludge compaction pump is air actuated it is important to have an adequate and reliable air source readily available. It is possible that the tannery compressed air would be adequate, but in the absence of information, compressed air generation is being included.

Design parameters

Air pressure required (psi) - - - - - - - - - - - - max 100

Air volume required, each pump (cfm)- - - - - - - max 125

Sizing and specifications

Number of compaction pumps specified - - - - - - 2

Air requirement vs. Winchester W.W.T.P. (x)- - - 2

Manufacturer - Kellog American
Oakmont, Pa.

Model no - A 462-TVI

Motor HP - 25

Capacity @ 100 psi (cfm) - - - - - - - - - - - - - 83

Cost estimate

Cost of Winchester compressor 1976 - - - - - - - $3,000

Cost of Winchester compressor 1978 - - - - - - - 3,500

Cost of compressor with 2x capacity (est)- - - - $5,000

Carrousel Oxidation Ditch

Design parameters

The volume of the oxidation ditch and the number and size of aerators is determined by the amount of oxygen demanding material in the feedwater entering the ditch. BOD and TKN each use oxygen. Both are substantially reduced in the primary treatment phase, BOD by 60%, and TKN by 40%. The residual material after primary treatment determines the load on the secondary.

Design MLSS (mg/l) - - - - - - - - - - - - - - - 7,500

Design F/M ratio - (BOD/MLSS) - - - - - - - - - - .06

Fixed design average swd in carrousel (ft)- - - - 13.4

Fixed design single channel width (ft) - - - - - 13

Oxygen required to satisfy BOD and TKN in the carrousel

1.5 x BOD + 4.6 x TKN

Oxygen rating per aerator O_2/hp/hr - - - - - - - - 3.5

Sizing and specifications

BOD present in combined flow raw wastewater (mg/l)	1,630
Residual BOD after 60% removal in primary (mg/l)	652
TKN present in combined flow raw wastewater (mg/l)	126
Residual TKN after 40% removal in primary (mg/l)	76
Average daily total flow (mgd)	0.8
BOD entering the secondary (lb/day)	4,353
TKN entering the secondary (lb/day)	507
Oxygen furnished per aerator (O_2/hp/hr)	3.5

Calculation of volume of carrousel

$\text{BOD} \div 0.06 = \text{MLSS (lb)}$

$4353 \div 0.06 = 72{,}550$

72,550 lb @ 7,500 mg/l = 1.15 M gal

1.15 MG = 152,520 ft^3

Calculation of surface area of carrousel

Volume (ft^3)	152,520
Average depth (ft)	13.5
Surface area (ft^2)	11,300

Calculation of total channel length

Surface area (ft^2)	11,300
Design channel width (ft)	13
Total channel length (ft)	870

Selection of number of channels

870 ft, total channel length required, indicates using a configuration of three channel circuits, six single channels, each 135 ft. long plus 80 ft of cross channel automatically included. This arrangement calls for three aerators.

Calculation of aerator horsepower required

Oxygen required = 1.5 x BOD + 4.6 x TKN

$O_2 = 1.5 \times 4353 + 4.6 \times 507$

$O_2 = 8{,}862$ lb/day

$\text{HP} = 8{,}862 \div (3.5 \times 24) = 105.5$

Three aerators will be used, see channel selection above.

Each aerator (HP)	40

Cost estimate

Volume of Winchester carrousel (gal)	380,000
Volume of Winchester carrousel (ft^3)	50,666
Volume of this carrousel (ft^3)	152,500
Comparative size of this carrousel to Winchester carrousel (x)	3.0
Cost of Winchester carrousel unit 1976	$197,700
Cost of Winchester carrousel unit 1978 (8%/year)	$230,597
Estimated cost of this carrousel unit (3.4x)	$593,100
Carrousel™ license fee ($.10/gal)	$114,985
Total cost, carrousel unit	$708,085

Secondary Clarifier

Although the primary section produces a clear effluent passing into the secondary, biological activity in the secondary generates a high level of suspended solids which have to be removed. They are relatively light in density and therefore somewhat difficult to separate.

Design parameters

Surface area at peak flow (gal/ft^2/day)	300

Peak flow = 2x normal average flow.

Sizing and specifications

Total average wastewater flow (gpd)	800,000
Peak flow (gpd)	1,600,000
Peak flow ÷ 300 (ft^2)	5,333
Diameter of 5,333 ft^2 circle (ft)	82
Diameter of final clarifier (ft)	82
Depth of final clarifier (swd) (ft)	8

Manufacturer: Clow Corp.
Florence, Ky.

Model: Veoflow. Periferal feed center sludge draw, center effluent outlet

Cost estimate

Volume of Winchester final clarifier (ft^3)	13,295
Volume of this final clarifier (ft^3)	42,664
Comparative size of this clarifier to Winchester final clarifier (x)	3.2

Cost of Winchester unit 1976	$33,500
Cost of Winchester unit 1978	$37,650
Estimated cost of this clarifier (3.2x)	$120,000

Sludge Return Pumps

These pumps return solids separated in the final clarifier to the oxidation ditch or to the sludge holding tanks as wasted.

Design parameter

Open pattern sludge pumps, standard construction, Midland Midwhirl or equivalent 100% return flow.

Sizing and specification

Total wastewater flow (gpd)	800,000
Average wastewater flow (gpm)	667
Manufacturer - Midland Pump Co.	
Model No. - Midwhirl 4WS - 4511	
Capacity (gpm)	350
Motor HP	30

Cost estimate

Pump and motor - each	$2,500
Two required	$5,000

Chemical Tanks, Piping, Power and Wiring

The foregoing items and costs as calculated, and summarized in table 16, are, in part, for equipment in place, including excavation where required. A major portion of the cost of construction of any treatment plant is for small tanks, pumps and piping, power and wiring. Preliminary estimates for these items, in the absence of engineering drawings, must be calculated from existing data. Appendix B lists costs for many of the major items in the Winchester treatment plant, total cost, and categorical costs for tanks, pumps, piping and electrical. Taken as a group these total $122,500 out of a total of $611,900, exclusive of housing and laboratory, or 20%. This percent of the total estimated cost of equipment for this exercise, as itemized in table 16, amounts to $380,700. However, some items of pumps are included in table 16, aggregating to $25,350, and thus must be deducted from the total. So doing leaves an estimated balance amount, to cover chemical tanks, piping, power and wiring, of $355,300

Housing

The dosing solution tanks, dosing pumps, flotation basin and sludge compaction equipment must be protected from weather if located in other than a tropical climate. Considering the size and possible arrangement of equipment it is estimated that a building about 200 ft x 100 ft would be required.

Specification

All steel, insulated, Butler building or equivalent

Forced ventilation at roof peaks.

Approximate size 100 ft x 200 ft.

Concrete slab floor with drains.

Cost estimate

Size of Winchester building -	
Length (ft)	104
Width (ft)	40
Floor area (ft^2)	4,160
Size of building needed, this exercise	
Length (ft)	200
Width (ft)	100
Floor area (ft^2)	20,000
Cost of Winchester building 1976	$87,500
Cost of Winchester building 1978 (est)	$102,000
Estimated cost of housing, this project	$400,000

This estimate has been reduced from $500,000 in deference to size, realizing that there would be some economy in scale.

TABLE 16. SUMMARY OF TREATMENT PLANT COMPONENTS AND ESTIMATED COST FOR CATEGORY 1 CHROME TAN-PULP HAIR CATTLEHIDE TANNERY

Item	Cost
Beamhouse flow holding, equalizing, and clarifying tank	$275,000
Tanhouse flow holding, equalizing, and clarifying tank	115,000
Constant flow head box	750
Constant flow supply pumps	3,000
Tanhouse wastewater flow pumps	2,000
pH sensing for acid waste flow control	1,700
Dosing pump - alum	250
Dispersed air generator	4,500
Coagulation cell	10,500
Dosing pump - polyelectrolyte	300
Bubble classifier	750
LectroClear solids flotation basin	80,820
Current rectifier	12,250
Skimmings pump	1,500
Solids slurry pumps	10,500
Sludge storage tanks	150,000
Sludge conpaction pump	2,800
Air compressor	5,000
Filter press	365,650
Heat exchanger	28,000
Carrousel oxidation ditch, complete	708,085
Secondary clarifier	120,000
Sludge return pumps	5,000
Total for above	$1,903,355
Chemical tanks, piping, power and wiring	355,300
Housing	400,000
Total	$2,658,700
Contingencies - 10%	265,800
Total estimated cost of project	$2,924,500

Estimated Cost of Operation

Examination and study of table 15 reveals that a cattlehide, chrome, pulp hair, tannery could be expected to emit effluent in slightly less volume per pound of raw hide or pelt than a shearling tannery, 6.1 gal/lb hide vs. 7.2. In terms of BOD and suspended solids, the cattlehide tannery wastewater contains about double the amount of the shearling tannery in each instance. Since most of the cost of operation is in removal and deposition of suspended solids, and in electric power for aeration to support biological activity for BOD reduction, it follows that the cost of operation of a treatment facility for a cattlehide, chrome, pulp-hair tannery would be about double that of a shearling tannery. Section 8 reveals a cost of $1.77 per thousand gallons of wastewater treated. Assuming some economy of scale the cost of operation for this model would be expected to be on the order of $3.00 per one thousand gallons treated.

PRELIMINARY DESIGN AND COST DEVELOPMENT FOR A WASTEWATER TREATMENT PLANT FOR A VEGETABLE TAN-SAVE HAIR CATEGORY 3 CATTLEHIDE TANNERY

Comparison of parameters in Table 15 for the category 3 tannery - veg tan, cattlehide, hair save - with category 7, shearlings, reveals a high degree of similarity. BOD, Suspended Solids, and volume of effluent, the most significant parameters, are all very close to being the same. In category 3, as in category 1, alkaline beamhouse wastes and acid tanhouse wastes are involved. Therefore the same approach to treatment, particularly as it pertains to the primary section, would be used as for the category 1 tannery. See schematic diagram, Figure 43. Also the same sources for background information are used in this exercise as used for the category 1 development preceding.

Basic Design Parameters - Vegetable Tan, Save Hair W.W.T.P.

Total flow (mgd)	0.3
Beamhouse flow (mgd)	0.215
Tanhouse flow (mgd)	0.085
Pollutant loadings - see Table 15	
Treatment plant operating day (hr)	20
Equalized beamhouse flow (gpm)	179
Equalized tanhouse flow (gpm)	71
Total equalized treatment plant operating flow (gpm)	250

Design and Cost Estimation of Components

Coarse Screening

Not included. See comments page 99.

Raw Wastewater Pumps

Not included. See comments page 99

Holding and Equalizing Tanks

See general comments page 99. The sizing of the two tanks in this case are calculated on the basis of volume needed to accomodate 10 hours of flow from each source, alkaline and acid.

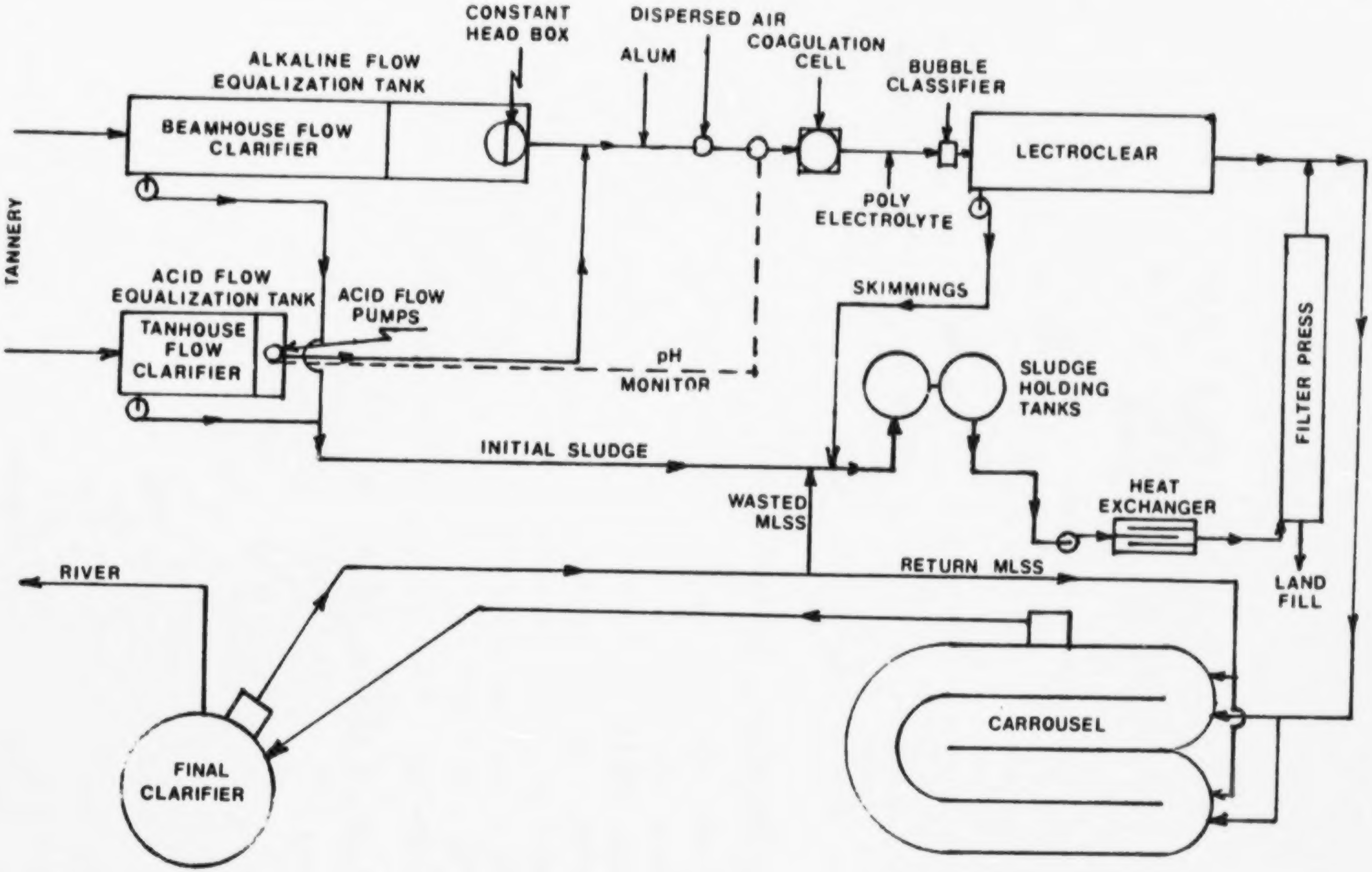

Figure 43. Schematic Diagram of Proposed Wastewater Treatment Plant for a Category 3 Vegetable Tan Save Hair Cattlehide Tannery.

Beamhouse flow holding, equalizing, and clarifying tank

This tank is of concrete rectangular. See general comments page 100.

Design parameters	
Detention time (hr)	10
Beamhouse flow (mgd)	0.215
Sizing of tank	
Volume - $\frac{10}{24}$ x 215,000 (gal)	89,600
Constant - gal/ft^3	7.5
Volume (ft^3)	11,944
Width (ft)	14
Length (ft)	65
Depth (ft)	13
Cost estimate	
Estimated cost - see page (ft^3)	$8
Volume (ft^3)	11,944
Construction cost	95,552
Total cost including sludge moving equipment (est)	$110,000

Tanhouse flow holding, equalizing, and clarifying tank

This tank is also constructed of concrete, rectangular, and of the same total concept as the beamhouse flow tank except that it is smaller. See comments page 100.

Design parameters	
Tanhouse flow (mgd)	0.085
Detention time (hr)	10
Sizing of tank	
Volume - $\frac{10}{24}$ x 85,000 (gal)	35,420
Constant - gal/ft^3	7.5
Volume - (ft^3)	4,722
Width (ft)	14
Depth (ft)	13
Length (ft)	26

Cost estimate

Estimated cost -	$8
Volume (ft^3)	4,722
Construction cost	$37,776
Total cost including sludge moving equipment	$50,000

Constant Flow Equipment

See general comments page 101.

Constant flow head box

See section 3

Design parameter

Horizontal cross-section (ft^2/gal/min)	32

Sizing of vessel

Total volume of beamhouse flow (gpd)	215,000
Design treatment plant operating day (hr)	20
Flow rate through weir box (gpm)	179
Cross sectional area needed @ 32 gal/ft^2/min (ft^2)	5.6
Diameter (ft)	3
Depth (ft)	6

Cost estimate

Fiberglass lay-up, standard mandrel	$500

Constant flow supply pumps

See general comments page 102.

Design parameter

Flow rate (gpm)	179

Sizing and pump specification

Capacity (gpm)	300

Manufacturer - Flyght Corp.

Model No. 6-CP-3126

Capacity - 600 gpm 9.4 HP

Cost estimate

Pumps - 2 $1,500 each	$3,000

Tanhouse Wastewater Flow Pumps

See general comments page 102.

Design parameter

Flow rate (gpm) - 71

Sizing and pump specification

Capacity, each (gpm) - - - - - - - - - - - - - - - - - 100

Manufacturer - Flyght Corp.

Model No. 4-CP-3105

R.P.M. - 1,750

Motor HP - 5

Cost estimate

Pumps - 2 $1,000 each - - - - - - - - - - - - - - - - $2,000

pH Sensing For Acid Waste Flow Control

See general comments page 103.

Design parameters

pH range -7.5 to 11

Power interruption level (pH) - - - - - - - - - - - - 9.0

Specifications

Manufacturer - Beckman Instrument Co.
Cedar Grove, N. J.

Model No. - 940 pH analyzer

Special feature - 10% dead band @ pH - - - - - - - 8.0 to 9.0

Cost estimate

Instrument - $1,500

Remote sensor connection (150 ft) - - - - - - - - - - 200

Total - $1,700

Dosing Pump - Alum

See general comments page 103.

Design parameter

1,000 mg/l to be added to combined beamhouse-tanhouse flow
Alum solution 45% solids @ sp gr 1.330, 11.1 lb/gal.

Sizing and pump specification

Equalized beamhouse flow (gpm)	179
Equalized tanhouse flow (gpm)	71
Total equalized flow (gpm)	250
Weight of flow (lb/gal)	8.5
Weight of flow (lb/min)	2,125
Weight of alum @ 1,000 mg/l (lb/min)	2.12
Weight of alum solution @ 45% solids (lb/min)	4.7
Volume of alum solution @ 11.1 lb/gal (gpm)	0.42
Pump capacity required (gpm)	±0.5
Manufacturer - Liquiflo Equipment Co.	
Series 34 3 gpm 0.5 in 316 SS	
Motor HP	0.75 DC
Variable speed - max rpm	1,725

Cost estimate

Pump and motor (est)	$250

Dispersed Air Generator

See Figure 5

See general comments page 104.

Design parameter

Ft^3 of air/100 gal of flow	0.5

Sizing and specifications

Manufacturer - Lighting Mixer Corp.	
Model No. - 4 - LBC - 200 5 in 316 SS	
Motor HP	2

Cost estimate

Generator with motor, complete	$3,500

Coagulation Cell

See Figure 6

See general comments page 105.

Design parameter

Effective residence time 2 minutes

Sizing and specifications

Total equalized flow rate (gpm)	250
Cell volume required for 2 min flow (gal)	500
Cell volume required for 2 min flow (ft^3)	67
Diameter of top section (ft)	7.5
Depth of top section (ft)	2.5
Diameter of bottom section (ft)	7.5
Depth of bottom section (ft)	1.8

Manufacturer - Local sheet metal shop

Cost estimate

Same as Winchester 1976 updated to 1978	$10,500

Dosing Pump - Polyelectrolyte

See general comments page 105.

Design parameter

12 mg/l to be added to combined flow

Polyelectrolyte solution strength - 0.2%

Sizing and specifications

Total equalized flow rate (gpm)	250
Weight of flow (lb/gal)	8.4
Weight of flow (lb/min)	2,100
Weight of polyelectrolyte needed @ 12 mg/l (lb)	.024
Solution strength (%)	0.2
Weight of solution needed @ 12 mg/l (lb)	12
Weight of solution (lb/gal)	8.5
Volume of solution needed (gpm)	1.4
Pump capacity needed (gpm)	1.4

Manufacturer - Liquiflo Equipment Co.

Series 36 - 5 gpm 0.75 in 316 SS

Motor HP	0.75DC

Variable speed 1,725 rpm max

Cost estimate

Pump and motor (est)	$300

Bubble Classifier

See Figure 7

See general comments page 106.

Design parameter

Surface area = 3 ft^2/100 gpm flow

Depth = 1 ft/100 gpm

Sizing and specifications

Total equalized flow rate (gpm)	250
Surface area @ 3 ft^2/100 gpm (ft^2)	7.5
Depth (ft)	2.5

Manufacturer - Local sheet metal shop

Cost estimate

Same as 1976 updated @ 8%/yr (est)	$500

LectroClear Solids Flotation Basin

See Figure 8

For description see section 3.

The design operating flow in this exercise is 250 gpm. The operating flow through the Winchester treatment plant is 300 gpm, very nearly the same. Therefore the same design and dimensions would satisfy the need in this case.

Cost estimate

Cost of Winchester unit 1976	$31,200
Cost of Winchester unit 1978	36,400
Number of electrodes	74
Cost of electrodes, each	$95
Total cost of electrodes	7,030
Total cost of flotation basin, installed	$43,430

Current Rectifier

Direct current is required for microbubble generation by electrolysis in the LectroClear flotation basin.

Sizing and specification

Same as Winchester. See section 3.

Cost estimate

Winchester cost (1976), including switches and wiring, installed	$10,500
Estimated total cost updated to 1978	$12,250

Skimmings Pump

See general comments page 108.

Sizing and specifications

Same as Winchester

Cost estimate

Pump, installed	$1,500

Solids Slurry Pumps

See general comments page 108.

Design parameters

Vaughn chopper pumps

Corrosion resistant construction

Sizing and specification

Total volume of beamhouse flow (mgd)	0.215
Suspended solids removal by sedimentation (est) (mg/l)	500
Constant (lb/gal)	8.5
Weight of beamhouse flow (lb/day)	1,827,500
Weight of suspended solids removed (lb/day)	914
Weight of solids slurry @ 1% solids (lb/day)	91,400
Weight of slurry (lb/gal)	8.5
Volume of beamhouse flow (gpd)	10,750
Average pumping rate @ 20 hr. day (gpm)	9
Total volume of tanhouse flow (mgd)	0.085
Suspended solids removed by sedimentation (est) (mg/l)	400
Constant (lb/gal)	8.5
Weight of tanhouse flow (lb/day)	722,500
Weight of suspended solids removed (lb/day)	289
Weight of solids slurry @ 1% solids (lb/day)	28,900
Weight of slurry (lb/gal)	8.5
Volume of tanhouse flow solids slurry (gpd)	3,400

Average pumping rate @ 20 hr. day (gpm) - - - - - - 3

Number of pumps required - 3 Interchangeable

Pump selection - Vaughn Chopper

Manufacturer - Vaughn Co., Inc.
Montesano, Wash.

Model 150 Motor 5 HP 1,750 rpm

Cost estimate

Pumps, each $3,500 - - - - - - - - - - - - - - - - - $10,500

Sludge Storage Tanks

These tanks are used to accumulate and store sludge during the entire daily wastewater flow period so that the filter press can be operated mostly during the normal working day. Table 15 indicates that the total hydraulic flow, and the incidence of suspended solids is no more in the veg-tan hair save cattlehide tannery than at Winchester, therefore, the same tank design and capacity can be used. See section 3.

Cost estimate

Two 12,000 gallon steel tanks

$3,500 each - $7,000

Sludge Compaction

See general comments page 110.

Since the wastewater in this exercise is expected to generate the same amount of sludge as the Winchester tannery effluent, the same equipment items and the same size of each can be used.

Sludge compaction pump

Specification

Manufacturer - Warren Rupp Pump Co.
Mansfield, Ohio

Model No. - SA3A

Cost estimate

Number needed - 1

Estimated cost installed - - - - - - - - - - - - - - - - $4,000

Filter press

See general comments page 111.

The press now in service at Winchester should be adequate for this use.

Specifications

Manufacturer - D. R. Sperry Co.
East Aurora, Ill.

Model No. 48 EHCL

75 rectangular, pyramid face pattern, 48 in by 48 in plates.
Center feed, corner vent.

Cost estimate

Cost of Winchester press 1976	$55,000
Cost of Winchester press 1978	$64,150

Heat exchanger

The unit now used for this purpose at Winchester should be adequate. See section 3.

Specifications

Manufacturer Eimco, Inc.

Length (ft)	14
Diameter (in)	8

Two pass.

Cost estimate

Cost of Winchester heat exchanger 1976	$4,000
Cost of same 1978	$4,665

Air Compressor

See general comments page 112.

The same size compressor as that in use at Winchester will suffice.

Design parameters

Air pressure required (psi)	max	100
Air volume required (cfm)	max	125

Sizing and specifications

Number of compaction pumps	1
Air requirement vs. Winchester	same

Manufacturer - Kellog American
Oakmont, Pa.

Model No. A-462-TVI

Motor HP	25
Capacity @ 100 psi (cfm)	8.3

Cost estimate

Cost of Winchester compressor 1976	$3,000
Cost of Winchester compressor 1978	$3,500

Carrousel Oxidation Ditch

Due to similarity of wastewater characteristics a ditch of the same size and detailed specifications should be adequate for this use. See section 3.

Cost estimate

Cost of Winchester unit 1976, exclusive of pumps, piping, valves, and electrical	$251,200
Cost of same, 1978	$293,000

Secondary Clarifier

See general comments page 114.

As is true with other components of this treatment plant the Winchester size and specifications will provide an adequate secondary clarifier. See section 3.

Cost estimate

Cost of Winchester secondary clarifier 1976	$33,500
Cost of Winchester secondary clarifier 1978	$39,000

Sludge Return Pump

See general comments page 115.

Same size as used at Winchester.

Specification

Manufacturer - Midland Pump Co.

Model No. - Midwhirl 4WS-4511

Capacity (gpm)	350
Motor HP	30

Cost estimate

Pump and motor	$2,500

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Housing

See general comments page 116.

The same steel Butler building will provide the protection needed for this application. See section 3.

Specification

Manufacturer - Butler Buildings, Inc.

Dimensions - 40 ft wide x 104 ft long.

Concrete floor with drains.

Cost estimate

Cost of Winchester Butler building 1976 - - - - - - - - -	$87,500
Cost of Winchester Butler building 1978 - - - - - - - - -	$102,000

Chemical Tanks, Piping, Power and Wiring

See explanation page 115. Refer to table 17 instead of table 16 for itemization of equipment and totalization of cost.

Cost estimate

Total cost of itemized equipment, this exercise - - - -	$667,745
20% of total cost -	133,549
Itemized cost of pumps, table 17 - - - - - - - - - - - -	24,050
Estimated cost of chemical tanks, piping, power and wiring -	109,500

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TABLE 17. SUMMARY OF TREATMENT PLANT COMPONENTS AND ESTIMATED COST FOR CATEGORY 3 VEGETABLE TAN SAVE HAIR CATTLEHIDE TANNERY

Item	Cost
Beamhouse flow holding, equalizing, and clarifying tank	$110,000
Tanhouse flow holding, equalizing, and clarifying tank	50,000
Constant flow head box	500
Constant flow supply pumps	3,000
Tanhouse wastewater flow pumps	2,000
pH sensing for acid waste flow control	1,700
Dosing pump - alum	250
Dispersed air generator	3,500
Coagulation cell	10,500
Dosing pump - polyelectrolyte	300
Bubble classifier	500
LectroClear solids flotation basin	43,430
Current rectifier	12,250
Skimmings pump	1,500
Solids slurry pumps	10,500
Sludge storage tanks	7,000
Sludge compaction pump	4,000
Filter press	64,150
Heat exchanger	4,665
Air compressor	3,500
Carrousel oxidation ditch	293,000
Secondary clarifier	39,000
Sludge return pump	2,500
Total for above	$667,745
Chemical tanks, pumps, power and wiring	109,500
Housing	102,000
Total	879,245
Contingencies - 10%	87,925
Total estimated cost of project	$967,170

Estimated Cost of Operation

Reference to table 15 reveals that there are no substantial differences in pollution load or volume, per pound of raw hide or pelt, between a cattlehide, veg tan, hair save, category 3 tannery and a category 7 shearling tannery. Therefore the operating costs presented in terms of a number of parameters in section 8 are applicable to this model.

General Statement

It must be recognized that the attempted technology transfer from a category 7 tannery to one of category 1 and one of category 3, as described in some detail in this section is not based upon actual experience. Obviously there has been no opportunity to apply the principles used in the Winchester treatment system on any other tannery wastewater. The concept suggested for receiving and combining two waste streams, alkaline and acid, only seems to have credibility based upon observations at the South Paris facility. As for biological activity in the oxidation ditch with respect to carbonaceous as well as nitrogenous bacteria strains it can only be speculated that similar results would be forthcoming if similar conditions would be established.

The factor of scale has not been taken into account in the calculations for construction of most of the high cost items, particularly in the chrome cattlehide model, hence more engineering refinement could reveal lower costs there.

SECTION 10

REUSE OF TREATED WASTEWATER

A definite potential would seem to exist for wastewater reuse at the Winchester tannery. River water, the primary source of plant process water, has substantial deficiencies. During the winter, the water temperature is well below the acceptable level for use, and during the summer, it can be too warm. At times of flooding contamination is considerable, and, indeed at all times it is far from pure. Thus the treated effluent water is consistently more uniform in some important aspects than the source from which it is drawn, and seemingly it could be used to advantage at almost any point in the process.

Recycled water does have some real limitations, however. The purpose of wash water is to carry off contaminants and other unwanted components, and some of these, particularly sodium chloride (salt), are non-compatible pollutants. These pass through the treatment plant and are present to almost the same degree after treatment as before. Consequently, in order to avoid compounding the existence of these materials in the process water, consideration of recirculation has to be performed in the light of this restraint.

Positive action should be taken to recover some of the energy used to heat process water. Wastewater taken after passing through the primary section of the treatment plant could be expected to be 40°F warmer in winter and 10°F warmer in summer than river water, a year-round average of 25°F. This represents heat that would normally be wasted but that perhaps could be recovered simply by recycling. On the other hand contaminants in the form of BOD, ammonia, TKN, and traces of residual dyestuffs still exist in this water.

During the secondary treatment step the continuous churning of mechanical aeration lowers the water temperature through evaporative cooling, and during the cold season direct heat transfer to the atmosphere occurs. Accordingly it might seem more reasonable to consider reusing water which has passed through the primary section only when concerned with heat recovery. However, the unique design of the carrousel with respect to resistance to atmospheric interference accomplishes heat retention to a large degree even in winter, so that the temperature differential between effluent water from the secondary clarifier, and river water becomes 30°F in winter and 5°F in summer, or an average of 17.5°F. While this is not as attractive as the primary effluent average differential of 25°F it is certainly appreciable and tips the scales in favor of using totally treated effluent in the reuse concept versus the somewhat warmer but less pure primary treated effluent flow.

The primary individual uses for water in a shearling tannery include initial pelt washing, soaking, make-up water for saturated brine, hose-down for clean-up, make-up water for pickle liquors and certain tan liquors, and wash and make-up water used during dyeing and fat-liquoring procedures. Note that all of these uses, with the exception of hose-down for clean-up, have the capacity for adversely affecting the quality of the product. Therefore any potential dangers not identified by rationalization must be determined through extensive trial before reuse is instituted. Each usage as above will be considered individually as to material and energy savings. Obviously the material savings will be limited to salt since the water to be used is the product of a purification process designed to remove other components which conceivably otherwise might be present in recoverable amounts.

RECOVERY AND USE FOR PELT WASHING

A large portion of the water used in this tannery is used for washing pelts. As received they contain much salt and animal soil. The water used is river water warmed as necessary, depending upon the time of year, to about 85°F, thus consuming energy. No salt is used at this point. In fact, a large part of this exercise is salt removal. Thus it becomes necessary to consider the impact of adding salt to the wastewater discharge system at this point from two directions rather than one if wastewater is reused, that in and on the skins, as usual, and that in the recycled wastewater if recycling should be practiced. The following facts help to examine this situation:

Pelts processed per day	3,600
Salt in and on pelts as received (lb/pelt)	1.5
Salt entering the system on pelts (lb/day)	5,400
Water used for pelt washing (gal/day)	150,000
Weight of water @ sp. gr. 1.000 (lb/gal)	8.345
Specific gravity of effluent	1.005
Weight of effluent @ sp. gr. 1.005 (lb/gal)	8.387
Weight of 150,000 gal of recycled effluent (lb)	1,258,050
Salt content of effluent (%)	1.2
Salt entering the system in recycled effluent (lb/day)	15,097

These figures clearly show that on the order of three times as much salt would return to the pelt washing operation as it is desired to remove, thus interfering greatly with the efficiency of this process step. Even if effective washing could be achieved by using effluent for the first batch washes, and fresh water for the last batch washes, recycling of even half as much salt would lead rapidly to saturation of the wastewater system with sodium chloride.

Energy Saving

As stated above, initial pelt washing does consume a considerable amount of energy in the use of wash water at 100°F. However, as discussed in the foregoing paragraph, the concept of recycling water containing salt to a process step that is primarily concerned with salt removal, prevents serious consideration of any other aspect of reuse, including energy saving.

RECOVERY AND USE FOR BRINE PREPARATION

Recycling of effluent for use in brine preparation could result in measurable savings. The lixator system for brine preparation, as practiced at Winchester, in itself is a purification process since make-up water is passed through a large bed of rock salt as a means to achieve saturation. This mode of reuse of treated wastewater seems to hold the greatest promise of success among those envisioned.

Material Saving

The following facts apply:

Salt used in brine preparation (lb/day) - - - - - - 30,000

Salt content of saturated brine (lb/gal)- - - - - - 2.65

Volume of brine used (gal/day) - - - - - - - - - - 11,400

Since 11,400 gal of saturated brine is consumed each day, on the average, this is the limit of recycle volume for effluent to be used for this purpose.

Weight of effluent @ sp. gr. 1.005 (lb/gal) - - - - 8.387

Weight of 11,400 gal effluent (lb) - - - - - - - - -95,608

Salt content of effluent (%) - - - - - - - - - - - 1.2

Salt content of 11,400 gal effluent (lb) - - - - - 1,147

Cost of rock salt as received (lb) - - - - - - - - - $.018

Value of salt recovered / day - - - - - - - - - - - -$20.65

Value of salt recovered / year (250 days) - - - - -$5,160

Energy Saving

Volume of wastewater possibly recycled for brine preparation (gal/day) - - - - - - - - - - - - -11,400

See calculation for energy saving page 138 - - - -

Yearly saving, heat recovery in brine preparation - $990

RECOVERY AND REUSE FOR HOSEDOWNS AND CLEAN-UP

No material or energy savings are envisioned for this reuse per se. Temperature or salt content are not important. Pumping costs would be no less than for fresh water. On the other hand, considering the wastewater volume as an entity, it is cooled, particularly in winter, through the addition of cold river water to it as a result of using such water for hose-downs and clean-up. Therefore, reuse of wastewater for this purpose could result in indirect energy conservation.

Energy Saving

Calculations are made as follows:

Volume of water used for hose-down and clean-up (gal/day) - - - - - - - - - - - - - -	15,000
See calculation for energy saving page 138 - - -	
Yearly saving, this use - - - - - - - - - - - - - - -	$1,300

RECOVERY AND REUSE FOR PICKLE LIQUOR MAKE-UP

Material and energy savings are possible in this category. Reused effluent would carry salt and heat energy into the pickle liquors which would not have to be provided otherwise. Effluent contains 1.2% salt, and is 17.5°F warmer, on the average, than fresh water. As stated before, untried quality considerations are paramount, and this use could only occur after extensive trial and experience.

Material Savings

The volume of water needed for pickle liquor make-up determines the degree of economy in effluent recovery for this purpose. The salt would automatically reduce the amount of saturated brine needed to reach the process specification for salometer. The following facts apply:

Volume of new pickle liquor (gal/day) - - - - -	12,000
Salt content of effluent (%) - - - - - - - - -	1.2
Weight of effluent (lb/gal) - - - - - - - - - - -	8.387
Salt content of 12,000 gal effluent (lb)- - - -	1,208
Cost of rock salt as received (lb)- - - - - - - -	$.018
Value of salt recovered / day- - - - - - - - - -	$21.74
Value of salt recovered / year - - - - - - - - -	$5,435

Energy Saving

Volume of wastewater recycled for pickle liquor, make-up (gal/day) - - - - - - - - - - - - - - -	12,000
See calculation for energy saving below.	
Yearly saving, this use - - - - - - - - - - - - - - -	$1,042

RECOVERY AND REUSE FOR TAN LIQUOR MAKE-UP

This reuse is much the same as for pickle liquor make-up. A common distribution system would serve both uses. Again, the salt would automatically reduce the amount of saturated brine needed to reach the required total salometer level.

Material Savings

Volume of new tan liquor (gal/day) - - - - - - - -	20,000
Salt content of effluent (%) - - - - - - - - - - - -	1.2
Weight of effluent (lb/gal)- - - - - - - - - - - - -	8.387
Salt content of 20,000 gal effluent (lb) - - - - -	2,013
Cost of rock salt as received (lb) - - - - - - - - -	$.018
Value of salt recovered / day - - - - - - - - - - -	$36.23
Value of salt recovered / year - - - - - - - - - - -	$9,058

Energy Saving

Volume of wastewater recycled for chrome liquor make-up (gal/day) - - - - - - - - - - -	20,000
See calculation for energy saving below.	
Yearly saving, this use - - - - - - - - - - - - - -	$1,738

RECOVERY AND REUSE - TOTALIZED ENERGY SAVINGS

Potential volume for saturated brine preparation (gal/day) - - - - - - - - - - - - - - - - - -	11,400
Potential volume for hose-down and clean-up - - -	15,000
Potential volume for pickle liquor clean-up (gal/day) - - - - - - - - - - - - - - - - - -	12,000
Potential volume for tan liquor make-up (gal/day)	20,000
Total potential volume effluent reuse (gal/day) -	58,400
Weight of effluent (lb/gal) - - - - - - - - - - - -	8.387

Weight of recycled volume (lb/day)	489,800
Average temperature in excess of river water (°F)	17.5
BTU recoverable / day	8,571,514
Fuel value of fuel oil (BTU/gal)	148,000
Equivalent gallons of oil recoverable / day	58
Cost of oil/gal	$0.35
Value of recovered heat / day	$20.30
Value of recovered heat / year	$5,075

TABLE 18. RECAP OF SAVINGS POSSIBLE THROUGH RECOVERY AND REUSE

Use	Material $ / year	Energy $/year
Brine preparation	5,160	990
Hose-down and clean-up	-	1,300
Pickle liquor make-up	5,435	1,042
Tan liquor make-up	9,058	1,738
Total	19,653	5,070
Grand Total	$24,723	

The combined saving is substantial. It is probably not factual to expect that all of the heat energy would be recovered, but since this represents by far the lesser portion of the total savings, the heat loss during transmission would not seriously impact the total.

In order to determine the viability of a proposed recycle system from the point of view of cost of operation and cost of construction versus savings to be realized, it is first necessary to make a preliminary design of an effluent return system.

Figure 44 is a schematic drawing of the tannery, the treatment plant, and a proposed effluent return system, more or less to scale.

ESTIMATED COSTS FOR EFFLUENT REUSE

Consideration of Operating Costs

Figure 44 schematically shows fresh river water entering the tannery for process use. The water is used almost entirely on the first, or ground floor, and is distributed in part to the same areas and use points as considered for reuse of treated wastewater. This water is pumped from the level of the river to the point of use through a vertical rise of about twenty feet. Purified effluent water would be pumped from a point about ten feet above the level of the river to exactly the same level of use. Thus the static head against which each of the pumps would be working is virtually the same in each case. The only other difference between the two would be several hundred feet of additional pumping distance for the returned effluent, incurring some additional dynamic head due to pipe friction. Again this is insignificant, assuming proper design and pipe sizing. It is also the case that the two differences are counterbalancing.

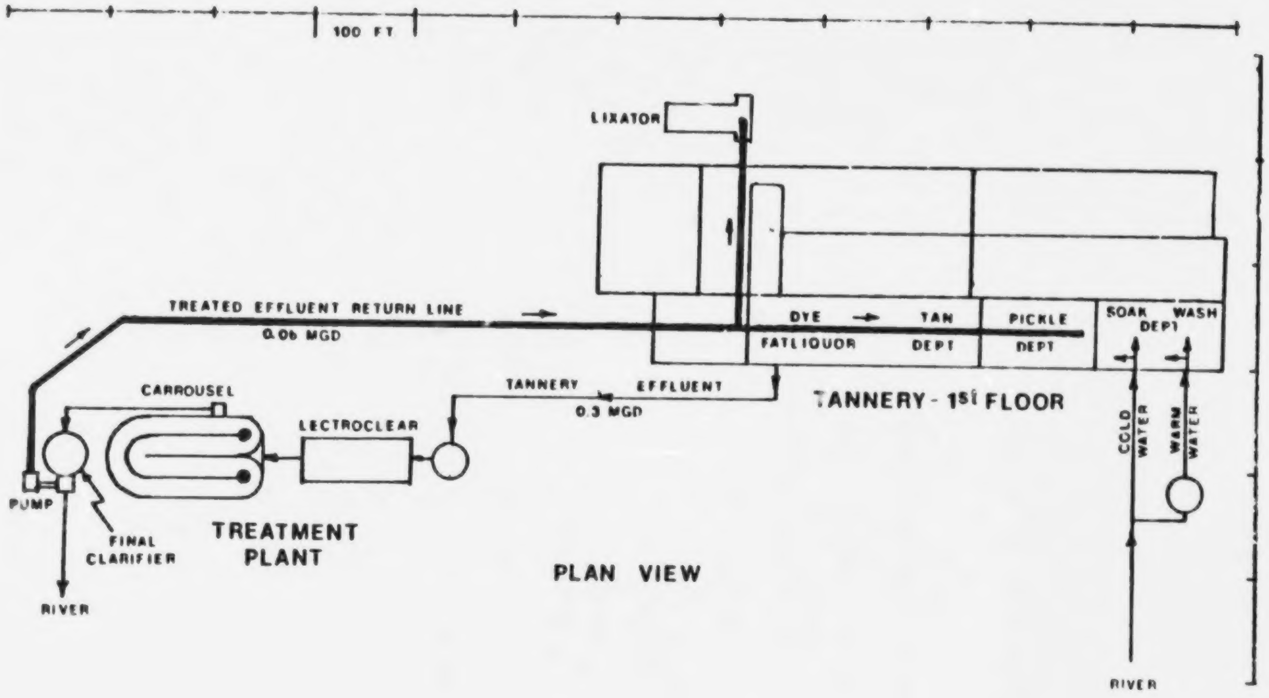

Figure 44. Schematic Diagram of a System for Proposed Re-use of Treated Wastewater.

The conclusion becomes, therefore, that pumping costs will be the same whether fresh water or treated wastewater is used where applicable.

Consideration of Construction Costs

Figure 44 shows that a return system for treated effluent would consist of a pump withdrawing treated water from the outfall from the final clarifier, and discharging into an underground (below frost level) return line to the tannery buildings, and thence to the points of use. All piping and valves would be PVC. The main would be of fairly large size all the way, with reduction fittings and smaller size pipe, valves, fittings, etc. at each point of use. Following are design parameters and cost estimates:

Pumps

Estimated volume to be reused (gal/day)	58,400
Time frame for reuse - minimum (min/day)	480
Average volume to be reused (gal/min)	122
Estimated peak volume (gal/min)	150
Pump specifications	
Capacity (gal/min)	150
5" suction, 4" discharge standard centrifugal, iron body, motor direct connected (HP)	30
Estimated cost of pump and motor, inplace	$3,000
Power supply, wiring and switches (est)	1,000
Labor (est)	500
Total for pump	$4,500

Weather protection (pump house)

Construction - Prefabricated insulated aluminum
Concrete floor
Size - 8 ft by 8 ft or standard.

Estimated cost inplace	$750

Pipe main to tannery building

Pump suction line

50 ft. 5 in PVC - $315/C ft.	$158
Foot valve and fittings	75

Underground to tannery.

750 ft 4 in PVC - $235/C ft	$1,762
Trench and backfill	1,500
Pipe fittings (est)	200
Labor (est)	750
Total	$4,445

Piping inside tannery buildings

Distribution main

700 ft 4 in PVC - $245/C ft	$1,715
Pipe fittings (est)	500
Labor (est)	1,500
Total	$3,715

Valving assemblies at each pair of paddle pits.

One 4 in to 2 in reducing tee	$10.40
One 2 in to 1 in reducing tee	7.60
Two 1 in valves PVC - $13.00 each	26.00
Two 1 in 45° tees - $1.46 each	2.92
Four ft 2 in pipe - $90.75/C ft	3.63
Two ft 1 in pipe - $42.00/C ft	.84
Total material for each pit piping assembly	51.44
Labor for each pit piping assembly (est)	25.00
Total cost of each pit piping assembly	76.44
Average number of pits in use	
Pickle Pits	40
Tan Pits	62
Total Pits to be equipped	102
Number of assemblies needed	51
Total cost of use assemblies	$3,900

TABLE 19. RECAP OF ESTIMATED EFFLUENT REUSE CONSTRUCTION COSTS

Item	Material	Labor
Pump	$4,500	$500
Pump house	600	150
Outside Main	3,695	750
Inside Main	2,215	1,500
Point of use assemblies	2,625	1,275
	$13,635	$4,175
Total	$17,810	

It is not realistic to estimate any project cost on labor and material alone. Overhead is always involved. It is customary to add on the order of 150% of the direct labor cost for this item, or, in this case, $6,262.00.

Grand total estimated cost of distribution system for reclaimed effluent wastewater.

Material and equipment	$13,635
Labor	4,175
Overhead	6,262
Total	$24,072

This estimated total of $24,072 for cost of equipment in place compares very favorably with the estimated annual saving of $24,734, especially in view of anticipated equality in operating costs. It must be emphasized again, however, that some of the reuses envisioned could seriously impair quality and a careful program of evaluation of each potential use would most certainly have to be undertaken before adoption.

USE OF FILTER PRESS CAKE AS FUEL

The 35% solids filter press cake that results from compaction of solids removed from the waste stream is ordinarily land-filled. This material has a fuel value, on a dry basis, of about 6,000 BTU/lb, compared to coal at 13,000 BTU/lb. The relatively low fuel value and high moisture content (65%) make the filter cake uninteresting as a fuel. A further consideration is the presence of trivalent chromium which poses the threat of formation of hexavalent chromium by oxidation during combustion. Production of such a highly toxic compound would make any burning of the filter cake a hazardous undertaking.

It is the conclusion, therefore, that the filter press cake is not a viable source of energy.

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APPENDIX A

LETTERS FROM J. L. WITHEROW TO J. A. REID CONCERNING ANALYSIS OF STANDARD SAMPLES FOR ANALYTICAL QUALITY CONTROL

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Industrial Environmental Research Laboratory – Cincinnati
Food and Wood Products Branch
Corvallis Field Station
200 S.W. 35th Street
Corvallis, Oregon 97330

July 1, 1977

Mr. John Reid
A. C. Lawrence Leather Company
1 Bridge Street
Winchester, NH 03470

Dear John:

Your analytical results for chrome, BOD_5, and COD arrived today, but not the results for NH3-N, NO3-N, P, KJN, or total P. The results sent are all correct, within one standard deviation of the answers obtained by others, except the BOD of Sample 2, and this was about 40% low. The lower BOD_5 values of sample 1, which is similar to the discharge is certainly more important to the project; however, being on the low side on this higher value might cause some problems in optimizing the oxidation ditch operation.

Very truly yours,

Jack L. Witherow
Project Officer

cc: Ken Barber

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Industrial Environmental Research Laboratory – Cincinnati
Food and Wood Products Branch
Corvallis Field Station
200 S.W. 35th Street
Corvallis, Oregon 97330

July 13, 1977

Mr. John A. Reid
A. C. Lawrence Leather Co., Inc.
1 Bridge Street
Winchester, NH 03470

Dear John:

Your analytic results for NH_3-N, NO_3-N, PO_4-P, KjN, and T-P arrived July 11, 1977. The standard values of the lower concentrations were 2.6, 1.2, 0.13, 2.1 and 0.85 mg/l, respectively. The standard values for the higher concentrations were 8.8, 6.7, 2.4, 38. and 4.28 mg/l, respectively. Seven of your results were "on the money." As you can see the PO_4-P were half the standard values and the lower KjN value was slightly more than 2 times the standard value. This suggests that dilution of the samples for these analyses may have been in error.

Since we have been concerned over NH_3-N measurement techniques I checked and found one standard deviation for concentrations 3 and 4 was 0.4 mg/l and 1.3 mg/l, respectively. This standard deviation was developed from an analyses by a number of laboratories in a "round robin" testing program. This is about a 15% variation from the mean. Your data indicates accuracy and no difference between the two methods of analyses.

Standard deviations for concentration 3 and 4 on PO_4-P were 0.04 and 0.4 mg/l, respectively. The standard deviation for concentration 5 for K_jN is 0.5 mg/l. Because of the large standard deviation in the PO_4-P analyses we would not reject your two values. The K_jN value of 5.04 mg/l would be rejected.

Thank you for running these standards. If you find dilution was the problem I would appreciate knowing. Toward the middle of the project or upon your request I will forward two additional sets of standard samples to aid in your quality control efforts.

Very truly yours,

Jack L Witherow

Jack L. Witherow
Food Products Staff

cc: Mr. Barber

APPENDIX B

INITIAL COST OF WINCHESTER TANNERY WASTEWATER TREATMENT PLANT

PRIMARY CLARIFICATION SYSTEM	
Holding tank	$62,100
Dispersed-air unit	3,500
Coagulation cell	9,300
Flotation basin	31,200
Electrodes	17,300
Rectifier and wiring	10,500
Chemical tanks, pumps and piping	50,700
Power and control wiring	34,200
Laboratory	8,900
Housing for above	87,500
Total	$315,200
SLUDGE DEWATERING	
Air-powered press pump	$3,500
Filter press and related sludge removal equipment	68,700
Switches and wiring, installation	5,000
Total	$77,200
SECONDARY BIOLOGICAL	
Carrousel license	$38,300
Concrete work	119,400
Aerators	51,800
Pumps, piping, valves, etc.	19,700
Electrical	12,900
Monitoring and control equipment	15,200
Excavation and miscellaneous	26,500
Total	$283,800
SECONDARY CLARIFIER	$33,500
TOTAL FOR SYSTEM	$709,700

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